

DISSERTATION

INVESTIGATING ENGINEERING STUDENTS' LEARNING FOR GLOBAL
PREPAREDNESS IN CURRICULAR AND COCURRICULAR ENGINEERING
EDUCATION

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ABSTRACT

INVESTIGATING ENGINEERING STUDENTS' LEARNING FOR GLOBAL PREPAREDNESS IN CURRICULAR AND COCURRICULAR ENGINEERING EDUCATION

Engineering as a profession has a significant impact globally in the creation and maintenance of the infrastructure and technology on which humanity relies. As resource constraints and dramatic global population growth challenge engineering's ability to support sustainable, appropriate development globally, the education provided for engineers is increasingly important for preparing engineering students to face the challenges of the present and future. Therefore, it is essential to understand how engineering students can become more globally prepared in their studies. The purpose of this study is to compare, through student experiences, different classes, and programs in engineering education designed to develop students' capabilities in global preparedness. The data for this project were collected through interviews with students who were taking part in different learning curricular and cocurricular classes and programs. In addition, data were collected through pre/post/retrospective-pre-student surveys when possible (for participant groups of greater than 30). The outcomes of this study are presented in three articles. The first article is a structured literature review of the global and professional competencies recognized by academia and engineering practitioners as key experiences and learning designed to improve undergraduate engineering students' global preparedness. The second article is a mixed methods analysis, comparing on-campus classroom

development of global preparedness and the impact of changing the context of the engineering class (from local to global) on student's global preparedness and professional competence development. The final article reports on the results of interviews with students participating in different study abroad and volunteer programs, to compare and contrast their experiences in and the impact of those programs. The value of this study is that universities and students may be able to use these results to better understand how to more effectively design and deliver classes and programs to increase the global and professional preparedness of engineering students.

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Chapter 1 - Introduction

Background

The United Nations Sustainable Development Goals (SDGs) require engineers who are defined by more than just their technical ability in their field(s) of engineering; these individuals must also be prepared to work globally through learning the professional skills and gaining the global preparedness or competence to practice engineering outside their native context and culture (United Nations, 2016). The KOM (competencies and mathematics learning) project in Denmark provides a clear and practice-oriented definition of competency as mastery (to a reasonable level, dependent on conditions and circumstances) of the essential aspects of life in the personal, professional or social domain of the area defined (Niss, 2003). The study also utilizes a common definition of the relationship between skills and competencies, where a skill is passive and procedural, something that can be learned but not necessarily understood or applied, while a competency is an active concept, the application of one or more skills through an individual's knowledge and ability. The application is subject to the realities of the social construct in which the skills are being practiced (Højgaard, 2009) that can be improved through training and development (Parry, 1996, p. 50).

The understanding of global competency, as it relates to engineering education, is relatively new (Henein, 2017) and in the United States, one of the first engineering education initiatives aimed at improving students' global competence was the "Changing Cultures" course taught at Virginia Tech and Colorado School of Mines (G. Downey, 2008; G. Downey et al., 2006). From this course, a movement began to prepare engineering students for more professional and global skills to increase their global competency. This movement now contains non-government organization (NGO) led sustainability programs from the Engineers for a

Sustainable World programs, Wicked Problems in Sustainable Engineering (Hess, Aileen, & Dale, 2014), Life Cycle Analysis + University (Dale et al., 2014) and the international development focused Engineers Without Borders Challenge created by Engineers Without Borders Australia (Cutler, Borrego, & Loden, 2010; Mattiussi, 2013), to institutional programs such as Massachusetts Institute of Technology's D-Lab (Cook & Thomas, 2012; Technology, 2015) and the Global Engineering programs at Purdue University (Jesiek, Dare, Thompson, & Forin, 2013; Sharp & Stevenson, 2013; Zoltowski & Oakes, 2014). Preparing students to be globally competent and skilled professionally is an increasing focus area for many disciplines of study, such as medicine (Cunningham, Kates, & Blauth, 2014; McGill, van der Vleuten, & Clarke, 2013), business (Barman & Konwar, 2013), and the physical (Celestino & Piumetti, 2015) and social sciences (Small, Nikolova, & Sharma, 2017).

One impetus for this change is economic necessity. The U.K. government's Leitch Review on "Prosperity for All in the Global Economy" demonstrates the importance of students being trained in "economically valuable skills" that would allow them to compete in an increasingly global marketplace for a country's economic future (Leitch, 2006). The report highlighted the need for employees to be competent and prepared to work as professionals globally, along with the role of universities in preparing students with holistic global and professional skills as appropriate to their field of study. The United States National Academy of Engineering's (2005) "Educating the Engineer of 2020: Adapting Engineering Education to the New Century" reflected that engineers of the future will probably have to be fluent in more than one language and will need to have the skills to enable them to adapt to an ever-changing socio-economic and global political landscape. Similar issues, in terms of integrating what has traditionally been seen as liberal education, into a technical vocation such as engineering can

also be seen in the medical and legal fields, as increased globalization requires medical professionals to understand non-western medicine and legal professionals to understand complex social structures in non-western countries (Sullivan, 2004).

The United Nations Educational, Scientific and Cultural Organization (UNESCO) proposed a new interdisciplinary movement for engineering education worldwide, called “engineering for development,” in response to this need (United Nations Educational Scientific and Cultural Organization, 2010). While there exist very few programs that specifically prepare engineers to work in international development, the few programs that do provide opportunities to demonstrate how engineering education is changing through the globalization of the engineering field(s). The present study investigated and compared a selection of undergraduate engineering curricular and cocurricular classes and programs available to students at a mid-sized, western U.S. university that provided a global context to engineering, along with more traditional non-globally orientated engineering programs in order to understand these programs’ differing effects on undergraduate engineering students’ preparedness to work in global environments and learning of the professional skills needed to be useful in these environs.

Statement of the Problem

There is an evident problem in the context of engineering education, as stated by industry and engineering stakeholders who claim that engineering education at the university level tends not to equip engineering students with the global and professional competencies needed to work in global workforces in either the corporate (American Society for Engineering Education, 2013; National Academy of Engineering, 2005) or non-governmental sectors (Bourn & Neal, 2008). The impact of this fundamental issue is substantial, with most engineering graduates being required to undertake up to two years of post-graduate professional training from their employer,

so that they are empowered with the competencies needed to perform their role as an engineer and to bridge the employment readiness gap (Freudenberg, Brimble, & Cameron, 2009).

There are two underlying philosophical barriers to engineering education preparing students to work globally. First, engineering in non-western countries has a history derived from colonial (Rostow, 1959), missionary (Canney & Bielefeldt, 2013), and military (Weiler, 1996) engagement, which is reflected in the positivist, neo-colonial engineering education paradigm (Johnston, 2001) that is taught in western countries today. Second, engineers' engagement in the field of international development emerged from cold war tensions (Lucena & Schneider, 2008) and the transition of technology from military to development use (Anand & Ravallion, 1993). These factors have been fundamental to the creation of the foundations of engineering education, which is still routinely criticized for its technology-focused (Ferguson, 1977) colonial thinking (Lucena & Schneider, 2008). Due to this foundation, most engineering degree programs at universities continue to be focused on the technical portion of engineering and do not provide sufficient learning in professional skills and global preparedness. The impact of such insufficient training is that most engineering performed by western-educated engineers in non-western countries at best follows Papanek's (1973) "design for the real world" and Schumacher's (1973) "intermediate technology" approaches to design and engineering in development, by which engineering practice in developing countries should be based on the transference and adaption of western technologies for non-western contexts. The practical outcomes of this issue can be seen in engineering practice all across the non-western world, such as the ongoing land and water rights issues created by the building of two hydropower projects in the Mekong River Basin in the Lao People's Democratic Republic due to a lack of due diligence and understanding of informal "local" land rights (Johns, 2015). In Africa, a 2009 report found that over 80% of water

handpumps in Mali were non-functioning, while 58% of pumps in nearby Ghana required repair to be fully functioning, contributing to the more than 50,000 broken, abandoned, or non-functioning pumps across Africa. This outcome, alongside the underlying human rights issues related to a lack of access to clean water, is also demonstrative of a failed investment of between \$215m and \$360m into necessary, local infrastructure due in large part to the deployment of inappropriate technology by western educated engineers (Skinner, 2009).

Conceptual Framework for the Study

Research into the most effective method of teaching vocational subjects, similar to and including engineering, emphasizes the importance of learning competence (the integration of knowledge, skills, and attitudes) in various areas to enable students to confront ill-defined, complex tasks and problems (Byrne & Mullally, 2014) that they should find in their vocational program and will undoubtedly find in their future professional careers (Baartman & de Bruijn, 2011). The teaching pedagogy often used to support students' integration of these three areas and, indeed, used to assess competence, is simulated or real engineering projects. For engineering in a global context, the impact and complexities of working globally or on global/transnational issues are suited to engineering problems that are situated in the context of the problem and enable students to experience, either in reality or through simulation, that context (Soria & Troisi, 2013). From these differing requirements, the conceptual framework developed utilizes as its basis professional and global competencies and an experiential learning model to build a context in which to situate students' learning of these competencies and to support their development of global preparedness (Ragusa, 2011).

Experiential learning theory.

Experiential learning theory was first formulated by Dewey (1939) and further codified by Kolb (1984) through, in part, the creation of the Lewinian experiential learning model in Figure 1. Experiential learning was for Dewey (1939) different from the typical style of learning of the period, which emphasized the gaining of knowledge in a vacuum; his idea was the formalization of learning through experience, which is more closely associated to the apprenticeship process, as learning happens through gaining and sharing experience. For Kolb (1984, p. 41) “learning is the process whereby knowledge is created through the transformation of experience. Knowledge results from a combination of grasping and transforming experience” (p. 41). Experiential learning is well suited to and often used in engineering education as it is an inherently vocational form of learning (Beard & Wilson, 2013, p. 17), given that engineering programs include real or simulated projects that are located in the realities and context of the career that students wish to pursue.

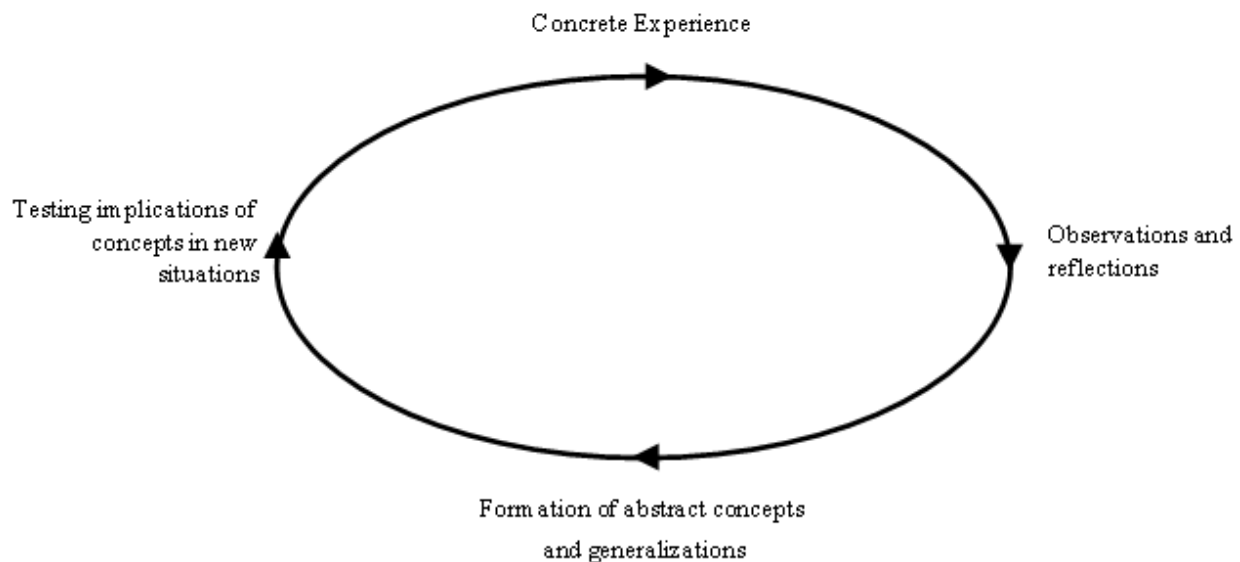


Figure 1. The Lewinian experiential learning model. Reprinted from *Experiential learning. Experience as the source of learning and development* (p.84), D. Kolb, 1984, Englewood Cliffs, NJ. Prentice Hall. Copyright 1984 by Prentice Hall

To be most effective, an experiential learning experience should engage the students in reflection, critical analysis, and synthesis and should create opportunities for students to take the initiative, make decisions, and be accountable for the results. It should provide opportunities for students to engage intellectually, creatively, emotionally, socially, or physically in the experience (Kyle et al., 2017), as this allows students to go through the different stages of the model shown in Figure 1.

Yamazaki and Kayes (2004) further developed Kolb's (1984) model to establish a taxonomy of skills necessary for the cross-cultural adaption of learning and to account for the influence of culture as seen in Figure 2, which is the direction followed and built on for this conceptual framework. Through this model, they added twelve skills in four thematic areas tied to stages of the Lewinian experiential learning model.

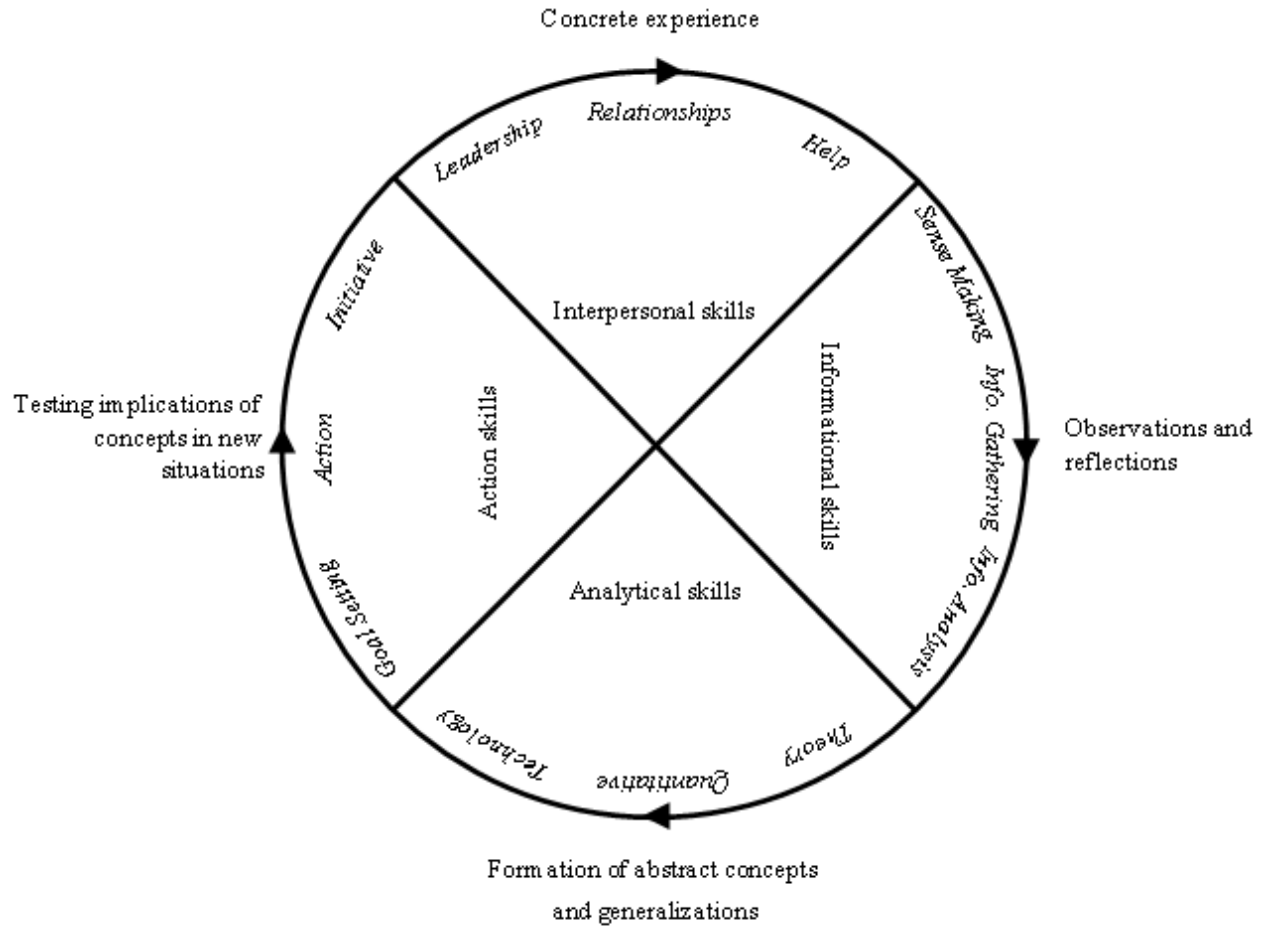


Figure 2. Experiential Learning Dimensions and Learning model. Adapted from *An experiential approach to cross-cultural learning: A review and integration of competencies for successful expatriate adaptation*, Y. Yamazaki & D.C. Kayes, 2004, *Academy of Management Learning & Education*, 4(3). Copyright 2004 by the Academy of Management

Given the five groups of classes and programs investigated in this study (see Table 1), the approach of layering skills into the model is seen as an appropriate basis from which to develop a conceptual framework for this study. The five groups are described based on Grandin and Hirleman (2009) classification framework developed for the National Science Foundation to categorize models for educating the global engineer.

Table 1

Grandin and Hirleman's (2009) framework applied to the classes and programs investigated in this study

Learning Opportunity	Short/ Long Term	Language	Cultural Exposure/ Immersion	Curricular Integration	Cultural/ Linguistic Prep.	Engineering-Specific	Institutional Commitment
One-semester first-year traditional course	Long	English	None	Yes	N/A	Yes	Engineering college level
One-semester first-year EWB Challenge design course	Long	English with some translation of materials	Some exposure through learning context	Yes	Some cultural intro.	Yes	Instructor level
Engineering students who will be studying abroad for a semester or more	Long	English (students travel to U.K., Australia, and NZ)	Through cultural osmosis, rather than educational intent	Yes	No	Yes	University level
Short-term study abroad programs for engineering students	Short	English, Spanish, and Chinese	Yes	Yes	Yes—students may have pre-work to prepare	China—Yes Costa Rica—No	University and instructor level
EWB Chapter students	Long (in the U.S.) Short (Int.)	English (some Spanish)	Some exposure through learning context. Yes, if traveling to community	No	Possibly, depending on the chapter's leadership	A mix of engineering-specific and fundraising, education, and management roles	Minimal

Global engineering competency.

Competency has a recent history as a framework within education practice derived from Bloom's (1956) taxonomy, which developed the idea of classifying learning into different stages of complexity, from the basis of remembering knowledge through the application of knowledge to the creation of new ideas or knowledge. As the idea of competency developed within the

educational field, it has become a core concept for post-secondary education; however, through this development, differing definitions and constructs have emerged for defining competency in different fields (Westera, 2001) and in different countries (Bristow & Patrick, 2014), so this conceptualization of competency should be seen as a United States definition of global competency, not a global definition. However, despite these differing conceptualities and approaches to defining competency, studies have found general agreement in the content of definitions of global competency (Olson & Kroeger, 2001). In most vocational fields, competency tends to be defined as acquiring and integrating into practice the knowledge, skills, and attitudes (KSAs) needed to achieve competency in the vocation (Baartman & de Bruijn, 2011; Kaslow et al., 2007). In this definition, knowledge is seen as being both factual information and procedural knowledge, which connects together factual information but cannot be easily communicated by itself. Skills are interwoven with knowledge and refer to both motor skills and cognitive skills. Attitudes are also further subdivided, with some researchers promoting separation between implicit (unconscious or pre-determined attitudes based on cultural, familial attitudes) and explicit attitudes, which are based on conscious decisions (T. D. Wilson, Lindsey, & Schooler, 2000).

Baartman and de Bruijn (2011) suggested that vocational students, such as engineers, learn the three elements of competence (knowledge, skills, and attitudes) through different tasks within formal or informal learning situations. They suggested there are two processes that occur within these learning situations: integration and transfer. Transfer process describes a student's ability to transfer KSAs learned in one task to a different task, context, or situation. The integration process refers to a student's ability to build connections between different KSAs to complete a new task, for example in engineering, bringing together students learning from

different technical classes to allow them to complete a final design project. For this study, all the learning situations that are being studied occur within real or simulated experiential contexts.

Global engineering competencies are defined by Johri and Jesiek (2014, p. 660) as “those attributes uniquely or especially relevant for cross-national/cultural engineering practice” (p. 660). This can be seen as additional skills to those needed to practice engineering in a domestic context, along with an expansion of those professional and technical skills that are relevant in a global context. Professional skills in engineering education were first formally recognized in 1996 by the Accreditation Board for Engineering and Technology in the publication of the Engineering Criteria 2000 (now known as the ABET Engineering Criteria), which recognized five technical skills of engineering (Shuman, Besterfield-Sacre, & McGourty, 2005, p. 41):

- Ability to apply knowledge of mathematics, science, and engineering;
- Ability to design and conduct experiments, as well as to analyze and interpret data;
- Ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
- Ability to identify, formulate, and solve engineering problems;
- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The criteria also identify six professional skills needed to be an engineer:

- Ability to function on multi-disciplinary teams;
- An understanding of professional and ethical responsibility;
- Ability to communicate effectively;

- The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
- A recognition of the need for and ability to engage in lifelong learning;
- A knowledge of contemporary issues.

These skills, as part of professional and global competencies, supplement the technical abilities of an engineer to allow them to function as engineering professionals through their capability to, for example, work with and for clients, manage budgets, and manage projects and teams in the U.S. and globally.

Allert, Atkinson, Groll, and Hirleman (2007) highlight that the emergence of professional skills and competencies (as separate from the core of science and math skills needed for technical engineering competence) came in response to the increasing need in industry for engineers who were able to meet an emphasis on product development and design. Similarly, global competence is emerging as recognition of the increasing challenges in engineering such as globalization of manufacturing, global resource constraint, economic and workforce globalization. There is an inherent danger to thinking of these competencies, technical, professional and global as separate areas of competence, when, they are in reality, part of the systematic, intertwined holistic whole of engineering practice. It should be hoped that in the future, this separation of competency into different silos ends and that the importance of students gaining competence in all the facets of engineering practice globally is recognized by engineering education. This is particularly important for global competence, as it should be asked, why are these competencies seen as being global only? It is equally important that these competencies, such as cross-cultural competence, are applied to domestic projects working with different communities and cultures in the United States. Therefore, what is referred to as global

preparedness in this study, and in engineering education generally, is competence in areas which should be equally important for engineers working on non-international projects as to those working on international projects.

Global preparedness.

Global preparedness is a relatively new term in education. There exists limited consensus around the term as its definition differs slightly depending upon the academic discipline (Hariharan & Ayyagari, 2016; Streiner et al., 2015) and the concept is theoretically grounded in the development of global citizenry theory (Zeichner, 2009). In this study, the terminology used is that outlined by the formative research into engineering global preparedness undertaken by Ragusa (2011, 2014) as part of a multi-institutional response to the challenges laid out in the National Academy of Engineering's seminal publication "The Engineer of 2020" (National Academy of Engineering, 2004, 2005). Ragusa defined global preparedness as built of four interrelated constructs: global engineering efficacy, engineering global-centrism, engineering global ethics and humanity, and engineering community connectedness (Levonisova et al., 2015; Ragusa, 2014). She sees professional and technical skills as cross-cutting and inherent within these constructs of global preparedness, as is shown in Figure. This notion is similar to, although structurally different from, other leading researchers, such as Allert et al.'s (2007) conceptualization of the global engineering profession as three different areas of competency (technical, global and professional) with skills inherent in each competency, as shown in Figure 3. Ragusa's model adds global preparedness and so competency as a context that includes professional and technical skills, rather than in parallel as in Allert et al. (2007) and Jesiek, Zhu, Woo, Thompson, and Mazzurco (2014) models. Other frameworks, such as Canney and Bielefeldt (2015) Professional Social Responsibility Development Model, similarly rethink skills

focused on competency constructs such as personal social awareness, professional development, and professional connectedness.

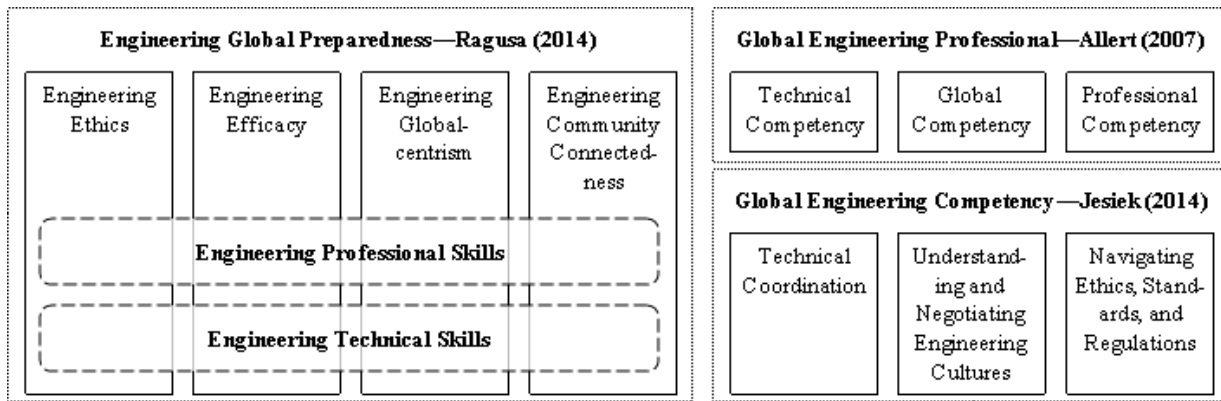


Figure 3. Comparison of different global preparedness conceptualizations from Allert et al. (2007); Jesiek et al. (2014), and Ragusa (2014)

Finally, as shown in Figure 3, Jesiek's (2014) development of global engineering competency similarly constructs three contextually specific dimensions of competency—technical coordination, understanding and negotiating engineering cultures, and navigating ethics, standards, and regulations—as a more practice-oriented conceptualization (Johri & Jesiek, 2014) of similar constructs and skills as compared to those contained within Ragusa' and Allert's models.

Ragusa's (2014) definition is a challenging concept to understand and to measure, as it is built of these four latent constructs, that is, unobservable factors or characteristics that are recognized as essential aspects of learning but are challenging to measure independently (M. Wilson, 2005). This challenge makes global preparedness difficult to measure by any traditional method, such as by examination, although newer educational practices in engineering education, such as the use of portfolios, have proven useful in the understanding of other latent constructs, such as leadership development (Yueh, 2013). Portfolios allow students to demonstrate a broader range of competencies than is possible through traditional exams due to the depth and

breadth of a portfolio; they also, importantly, allow students to demonstrate growth (Mokhtaria, 2015). In this study, questionnaires are used in a pre, post and retrospective format (Gliner, Morgan, & Leech, 2009) to track students' growth change through different educational experiences. Interviews were also used for data collection as this method, similarly to portfolios, provides a greater depth of information and a more holistic overview than is possible through examinations or questionnaires (Knupfer & McLellan, 1996; Kvale, 2009). Interviews also provide the opportunity for the researcher to explore and clarify responses from the interviewee and to explore emerging themes, which is not possible through investigating artifacts such as examinations and portfolios (Alshenqeeti, 2014).

The constructs upon which global preparedness is built are similar to the professional skills needed by engineers, with the addition of global contextualization, that is, the ability of the individual student to apply the professional or technical skill based on differing global socio-economic, political, and cultural realities (Hariharan & Ayyagari, 2016). Table 2 aligns the professional skills considered necessary for global engineers in four studies undertaken in the United States, Australia and the United Kingdom with the subconstructs in Ragusa's (2014) conceptualization of global preparedness.

Table 2

Subconstructs of EGPI instrument (Ragusa, 2014) with aligned professional skills from four studies

Sub Construct (Ragusa, 2014)	Description (Ragusa, 2014)	Professional Skills (American Society for Engineering Education, 2013; Bourn & Neal, 2008; Fisher, 2014; King, 2008)
Global Engineering Ethics	A depth of concern for people in all parts of the world, sees a moral responsibility to improve life conditions through engineering problem solving and to take such actions in diverse engineering settings	Cross-cultural skills, ethics, global awareness, sustainability, disciplinary knowledge
Global Engineering Efficacy	The belief that one can make a difference through engineering problem solving; through personal involvement in local, national, and international engineering activities that support achieving greater good using engineering problem solving and technologies	Critical thinking, civic responsibility, creativity, strategy, problem-solving, global awareness, disciplinary knowledge
Engineering Global-centrism	Valuing what is good for the global community, not just one's own country or group, in engineering-related efforts; making judgments based on global needs for engineering and associated technologies, while not focusing on ethnocentric standards	Global awareness, sustainability, communication, teamwork, environmental awareness, problem-solving
Engineering Community Connectedness	Awareness of humanity and appreciation of interrelatedness of all people and nations and the role that engineering can play in improving humanity, solving human problems through engineering technologies, and meeting human needs across nations	Communication, cross-cultural skills, ethics, humanitarianism, innovation, teamwork

Engineering Global Preparedness is, therefore, a reasonable construct with which to understand the differences and similarities between the five groups included in this study.

Global preparedness conceptual framework constructed for this study

Global Preparedness is defined by Ragusa (2011) as engineering students' preparedness for global workplaces and is measured by their competency in communication, professional ethical responsibility, understanding of global issues, and lifelong learning. This study examines the competencies contained within the subconstructs of Ragusa's model that are specifically related to the global and professional aspects of engineering (those that are technical, or theoretical design related are not); it also examines the social and contextual influences on students' knowledge, skills, and attitudes related to global engineering. This study also recognizes the importance of but does not investigate the informational and analytical skills or technical competencies shown in Figure 4. It focuses on the action and interpersonal skills or global and professional competencies, in the context of the engineering global preparedness model.

Figure 4 also suggests a modification to Kolb's (1984) model, based on two areas of critique that some researchers have explored. Kolb's (1984) model has been described as being theoretically limited, as it decontextualizes the learning process and does not account for many factors that affect learning (Kayes, 2002). In this proposed model, items from within the subconstructs of the Global Preparedness (Ragusa, 2011) model have been added as a layer of relevant (to the global context) factors that affect learning. A second relevant critique is that Kolb's (1984) model does not recognize the influence of individuals' backgrounds on their learning. Vygotsky's (1978) social learning theory suggests that an individual's learning is centered in an individual's own social and historical position, and the social learning they have from that background. To include these influences on the participants in this study a

demographic questionnaire was utilized to understand students' background regarding gender, parental college experience, nationality, international experience, age, and other differences.

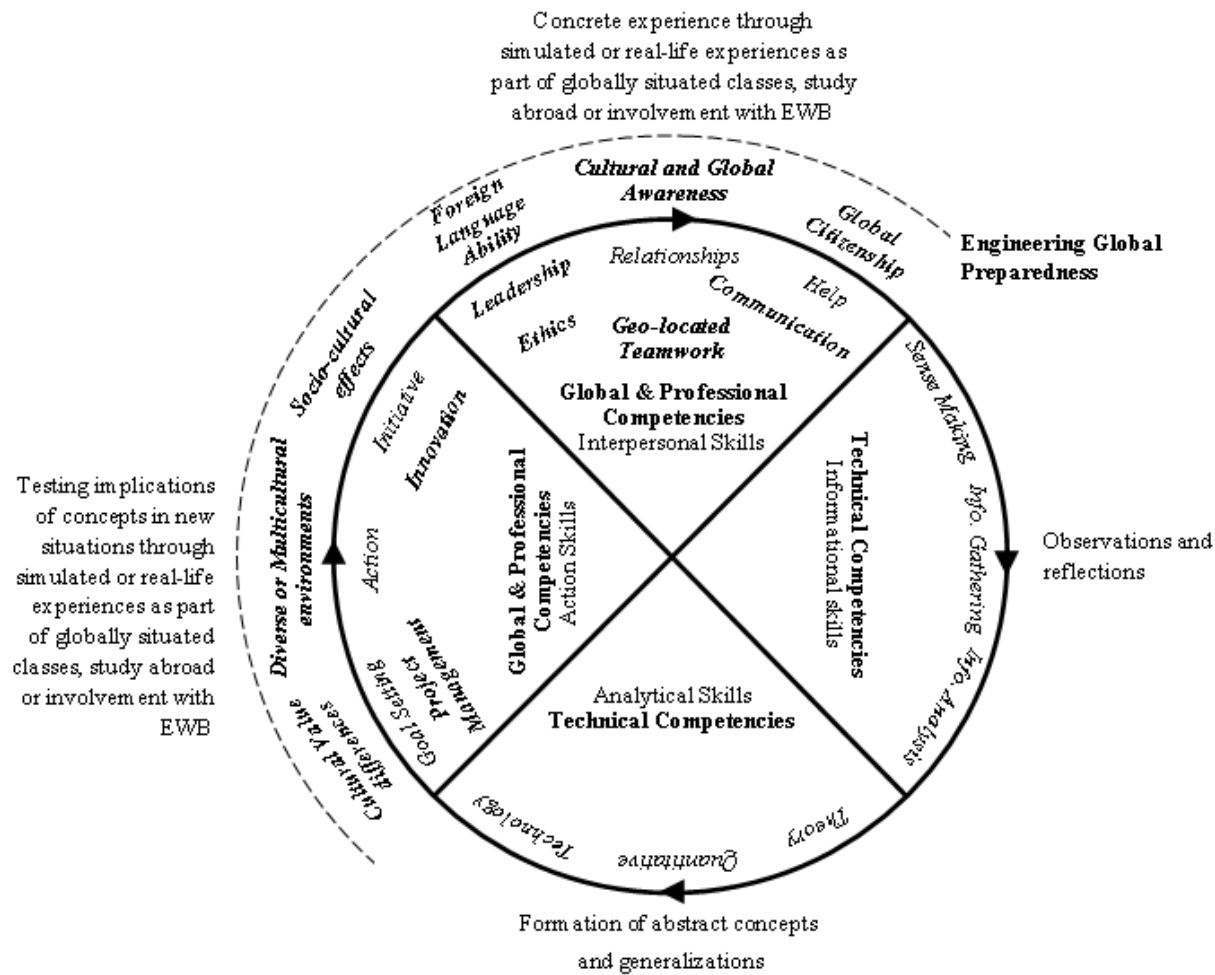


Figure 4. Engineering Global Preparedness Conceptual Framework. Adapted from *An experiential approach to cross-cultural learning: A review and integration of competencies for successful expatriate adaptation*, Y. Yamazaki & D.C. Kayes, 2004, *Academy of Management Learning & Education*, 4(3). Copyright 2004 by the Academy of Management

Including the contexts and situations in which the learning occurs; classroom, study abroad or in the EWB chapter, also recognizes that no learning is decontextualized, and that the context or situation in which the learning occurs also affects the students and their learning (Gilbuena, Sherrett, Gummer, Champagne, & Koretsky, 2015).

An important clarification to note with this model is that it is a continuous circle and that an important part of experiential learning is that after the experience, there is a process of reflection to support students translation of their learning through the experience into their overall knowledge. Eyler, Giles, and Schmeide (1996) in their guide to reflection in service learning, found from a study centered in understanding the effect of students reflecting on service learning programs, that reflection practices should be;

- Continuous, the reflection process must take place before, during and after the experience to be fully useful
- Challenging, effective reflection involves students getting out of their comfort zones to make new connections between concepts, ideas, and practice.
- Connected, useful reflections should create connections between the experience or project and the student's discipline and academic studies.
- Contextualized, reflection should be framed in a manner that is appropriate for the context that the experience or project took place in.

Reflection as an intentional practice supports engineering students development of competency in three ways; it helps students make sense and fill cognitive gaps by extrapolating their learning from the experience, it supports double-loop learning as a transformative technique (Synnott, 2013) by having students reflect on changes and questions they have had through the process and finally, it helps them to assimilate or accommodate new knowledge into their existing ways of knowing (Turns, Sattler, Yasuhara, Borgford-Parnell, & Atman, 2014). Without intentional reflection, students may not translate their experience to their professional, global and technical competence within their field of study. Several studies have found that while there is a dearth of reflection methodologies that are widely utilized in engineering

education (Gough, Janega, & Dalo, 2018; Turns et al., 2014), there are several methods that have proven successful, such as journaling throughout the experience, written assignments and group reflection discussion sessions (Wegner, Stefan M. Turcic, & Hohner, 2015).

Finally, terms such as *global* and *international* are utilized throughout this study, which does not align with the principles of the modern critical lens and international development thinking. Critical methodologies such as critical race theory and feminist research have increasingly adopted the term *trans-national* from the 1970's movement of historians and political sciences in order to move research beyond the positivist "global" approach, to develop studies that were more culturally specific and de-colonialized (Clavin, 2011; Jooste & Heleta, 2017; Maitra, 2013). While the term *trans-national* itself has received criticism, namely that it reinforces colonial structures and national borders with its named focus on "nations" (Maitra, 2013), this study is not designed to suggest a curricular paradigm that is "global" or globally transferable or even trans-national. Instead, this study refers to engineering educational curricular and cocurricular programs within the context of a mid-sized, western U.S. university which gives students the preparedness to approach engineering outside of the context derived for them by their instructors' own engineering practice contexts. While the results may be transferable to other universities with a similar culture located within the United States, or to universities in countries with similar cultures to the United States, no such claims are made by this study. Similarly, most of the literature contained within this study is written by authors within the United States or countries such as the United Kingdom and Australia that have similar cultures and educational frameworks within engineering and engineering education. To that end, the term *global* is preferred to *trans-national* throughout as, despite the critique of "global" as being U.S.-centric (*international* is similarly critiqued for being Eurocentric), it is the commonly

used parlance within United States engineering education (Johnston, 2001). There is however some emerging discussion in the US about a change in terminology, given that knowledge isn't often global, it can be seen as being international or trans-national (G. L. Downey & Beddoes, 2011, p. 4). This study also recognizes that globally, engineering education and the engineering profession in general, are at differing stages in their understanding of, and their level of, global and professional competence preparation of engineering students and practicing engineers. There is also not complete agreement around the definition of some of the terms, such as global competency and professional competency and these terms, and the skills contained within them have nuanced differences in meaning to the engineering profession and engineering educators around the world.

Instructor ability to support students professional and global competence development

A question, which is not explored in most studies related to global and professional competence is the ability of instructors to support engineering student's global competence development. The majority of instructors individual professional and global competence is developed through their own personal journey, or geography, and many of the experiences from which they develop competence are found outside of academia (G. L. Downey & Beddoes, 2011, pp. 3-45). As the preparation of students to work in international careers is becoming increasingly important, there is a recognition that global competence is an area in which many instructors are lacking and there are efforts at various institutions to support faculty developing their own competence to allow them to teach and support their students. Aligning faculty competency development with the conceptual framework in Figure 4 suggests that faculty learn through the same experiential process as students, through observing, formulation of ideas,

testing, practice and reflection (Dewey, 1939). The Association of Civil Engineering has advocated for academic faculty members to gain professional competence by joining industry in part-time or temporary, internship roles. While this program is limited in application, has had significant positive impacts on the faculty who have taken advantage of this opportunity (Chou & Nykanen, 2009), results which are echoed in a similar program at VIT University in India (Narayanan, Adithan, & Creese, 2011). A vertical education enhancement program for faculty at Alabama A&M University takes this further, by recognizing that faculty need international experiences and so the university promotes and supports faculty to also undertake research with international partners, and provides funding for faculty to attend, or create, international meetings, workshops and events (Egarievwe, 2015). However, from these studies, it is questionable if faculty international experiences have the structured reflection needed for these to be effective experiential learning opportunities for faculty.

Presentation of results

The results of this study are presented in the form of three articles. The first article is a literature review of the professional skills and global competencies engineers need to be globally prepared and the teaching practices currently used. This review is based on a structured review of current engineering education research. The second article is developed from the results of the global preparedness questionnaire developed by Ragusa (2011, 2014) and given to students in two first-year engineering design courses. The conclusions in this second article are supported by cases and reflections from interviews with select students in those courses. The final article will uncover and validate themes developed from exploring students' experiences, through interviews with students in the five different classes and programs. Ary, Jacobs, Irvine, and Walker (2013) define two distinct forms of qualitative research: participant observation where

the researcher is a participant of the study and non-participant observation where the researcher observes but is not a participant. While the researcher has had a little involvement as a guest speaker in one of the classes included in this study, a non-participatory analysis technique is still appropriate. Qualitative Content Analysis (Roberts, 2000) is a well-recognized method of analysis that has enjoyed a renaissance in popularity due to software packages simplifying its applicability to large sources of data, such as interview transcriptions. It is a very direct method that supports the voice of the participants in a way that is transparent to readers. The inferences drawn from this are systematic and explicitly informed by the participant's words so are more transparent to the reader (Krippendorff, 2004). Qualitative Content Analysis will be utilized to develop emergent themes, which will be added to the themes adopted from the four EGPI instrument constructs before open coding develops and supports the themes examined.

Research Questions

The chapters of this study follow the format of a three-article dissertation; the first chapter provides the background and organizational rationale for the study, and chapters two, three and four report the methods and results for each part of the study in the format of a journal article. The first article is a structured review of the literature about the competencies and professional skills needed by global engineers and the methods used to teach these competencies to undergraduate engineering students; this article answers the following questions:

- What professional skills and global competencies for engineering graduates are recognized as fundamental by key stakeholders in global engineering practice and engineering education?

- From the literature, what are the current educational practices and models for developing global preparedness and relevant professional skills through the undergraduate engineering core curriculum and optional or cocurricular classes and programs?

The second article compares two first-year civil engineering design classes for their effect on students' global preparedness and their learning of associated professional skills. One class undertakes the EWB Challenge, an international development design challenge, while the control class undertakes a traditional, U.S.-based project. This mixed methods article utilizes students' responses to a survey, supported by student interviews, and answers the following research question:

- What, if any, differences are there between a globally oriented project (EWB) and a traditional introductory course on the development of global preparedness and professional skills over a one-semester first-year civil and environmental engineering course?

The third article develops an understanding of engineering students' experiences from interviews with engineering students in different curricular and cocurricular classes and programs, both on campus and studying or volunteering abroad, and how these experiences affect students' global preparedness and professional skills by answering the following question:

- Comparatively, how do engineering students at a mid-sized, western U.S. university reflect on the effects of different domestic and global curricular and cocurricular classes and programs on their engineering global preparedness and professional skills?

Significance of the Study

The United States (and the United Kingdom) have become the leaders in engineering education ontology, epistemology, and pedagogy due to their historical role in the creation of the field (Albu, 1980), their economic position in the world, their role in accreditation of engineering education (Anwar & Richards, 2013), and the ease of transference of their engineering education models around the world, due to the emerging educational linguistic preferences of other countries for English (Phillipson, 1996). Therefore, engineering education research undertaken in the United States has additional significance, as it is often modeled by other countries' education systems in planning and developing their engineering education (Takayama, Sriprakash, & Connell, 2016; Zhen-dong, 2004).

Within this overall global system of engineering education research and practice, the present study is significant for two reasons; firstly, it builds on the existing knowledge of engineering global preparedness and the professional skills needed to work in engineering globally and international development, an emerging area of research in engineering education (Hariharan & Ayyagari, 2016; Streiner et al., 2015). Through the comparison of different curricular and cocurricular classes and programs, this study develops an understanding of the relative impact of international travel and curricular support to students' global preparedness. Secondly, by investigating students' comparative global preparedness and associated professional skills gained through different curricular and cocurricular classes and programs, the study can develop an understanding of the value of international exposure through these classes and programs.

The impact of changes on engineering education cannot be understated, as engineering and engineering education face a critical issue. In the latest published figures, the U.S. Congress

Joint Economic Committee (2012) predicts that the United States will add approximately 10% more jobs to the engineering workforce over the ten-year period from 2010 to 2020; at the end of 2015, engineering colleges across the United States had graduated 3.6% more engineers, across all engineering disciplines, than in 2010 (Yoder, 2016). However, this growth is lower than the overall national trend. In 1985 STEM subjects provided 24% of the bachelor's graduations; in 2009 this had fallen to 18% while master's graduations show the same trend, with a fall from 18% to 14% over the same period (United States Congress Joint Economic Committee, 2012). In the United Kingdom, a recent study demonstrated that there is a 20,000-person gap between the number of engineering graduates each year and the number of jobs to be filled, despite a 9% year-on-year increase in undergraduate and master's degree graduation levels from 2014 to 2015 (EngineeringUK, 2017). This gap is currently being filled by immigrants from other countries, leading to a brain drain in the engineering capacity from countries that are not able to offer competitive salaries or standards of living (United Nations Educational Scientific and Cultural Organization, 2010). Engineering educational reform is vital to encourage more students to study and remain within the field of engineering and to encourage more diversity within engineering student bodies. Research has shown that increasing global learning within engineering education supports both of these aims (Danielak, Gupta, & Elby, 2014; Grudzinski-Hall, Jellison, Stewart-Gambino, & Weisman, 2007; Miller, 2016; Sperandio, Grudzinski-Hall, & Stewart-Gambino, 2010). Orienting engineering education to contain more global learning also provides engineering graduates with the competencies that industry requires for the global landscape within which the graduates operate (American Society for Engineering Education, 2013; Passow, 2012; Passow & Passow, 2017).

Definition of Terms

- International development is a complicated term to define, given its extensive use and change of use through history. In its broadest use, it includes a range of disciplines and interdisciplinary endeavors (including engineering) with the aim of improving the quality of life for people around the world. It can include economics, social development, humanitarianism, foreign aid, poverty alleviation, law and governance, healthcare, food and water security, capacity building, education, human rights, children's rights, women's rights, disaster preparedness and post-disaster reconstruction, infrastructure development, and sustainability (Greiman, 2011). In this study, *international development* is used in this broadest sense and is used as a synonym for *global development*.
- Engineering students in this study refer to individuals who are registered as first- to fifth-year undergraduate engineering students in the college of engineering at the university studied.
- Curricular learning experience in this study is defined as any learning experience that is assessed by an instructor at a mid-sized, western U.S. university and, after satisfactory completion, can be counted by the student taking part in the curricular learning experience toward their degree (i.e., the student can be awarded degree-worthy credit for the course). The learning experience is not necessarily an on-campus or in-the-classroom learning experience as study abroad courses and transfer credits from other institutions are also included.
- Cocurricular learning experience in this study is defined as learning experiences that may or may not be supported by instructors or other professionals but do not count as degree-

worthy credit. Cocurricular learning experiences can be thought of as volunteer opportunities, which students may undertake for their development but for which they may receive no formal, university recognition.

- Service learning project integrates meaningful community service with instruction and reflection into a curricular learning model.
- The engineering design project is a learning model (either curricular or cocurricular) that is modeled to replicate an engineering design project in the workplace, in that there are a design problem, project team, and a client for whom the project team must develop a solution or management/mitigation option. The project and client may be fictional or real, depending on the learning model.
- NFP, not-for-profit organization, or non-profit organization, is an organization that does not conduct activities for profit, but normally does so for a purpose. In the United States, these organizations tend to be tax-exempt and domestically focused. NFPs in the United States that are internationally focused tend to be referred to as NGOs or INGOs.
- NGO or non-governmental organization is a type of not-for-profit organization defined as being separate from government control, although it may receive funding from government sources. Recognizable examples of NGOs in the United States are organizations such as Habitat for Humanity and Engineers Without Borders USA, which are domestically based but work on projects in other countries. In the United States, the definitional difference between an NFP and an NGO tends to be the geography of their work; if their focus is primarily within the United States, they are referred to as NFP, but if their focus is mixed or mainly outside the United States they are known as an NGO.

- INGO or international non-governmental organization is the name typically given to larger organizations that operate in more than one country such as the International Federation of Red Cross and Red Crescent Societies, the parent organization of the American Red Cross.
- EWB or Engineers Without Borders is a global movement of engineers and engineering students. There are separate non-government organizations in different countries, each of which has slightly different goals and methods but almost all of whom work with engineering students in their country in partnership with communities and NGO partners in developing countries. Three different EWB groups are referenced in this study. EWB-USA is an NGO based in Denver, Colorado, and has 288 student and professional chapters across the United States (Engineers Without Borders USA, 2015). The student chapter at this university is one of the groups included in this study. EWB-UK is a similar organization in the United Kingdom; although it has more of an engineering education focus than EWB-USA, it is also the former employer of the researcher and author. EWB Australia is a similar engineering education-focused NGO based in Australia; they created and maintain the EWB Challenge which is utilized in one of the classes investigated as part of this study.

Research Design

This study was conducted as a mixed methods study with three parts. Firstly, the researcher performed a structured review and analysis of current literature to uncover current thinking and research related to the global competencies and professional skills needed by engineering students to be prepared to work in a global workforce (presented as the first article). Secondly, students in two first-year civil and environmental engineering classes were asked to take the Engineering Global Preparedness Index (EGPI) instrument (Ragusa, 2011) at the beginning and end of their course (presented as the second article). Finally, students from those two courses, along with students from three other classes and programs in the engineering college, were asked to take part in 20-40 minute semi-structured interviews (presented as the third article).

Participants.

This study took place at the College of Engineering at a mid-sized, western U.S. university, between January 2017 and May 2018. All the participants were engineering undergraduate students in the College of Engineering, and quantitative data were collected in first-year civil engineering classes, while the interviews took place in meeting rooms within the college building or within the student center. The number of students, the data collection method, and period for the different study groups is shown in Table 3.

Table 3

Different groups within this study

Learning Opportunity	Number of Students interviewed	Number of Students surveyed	Data Collection Period
One-semester first-year traditional introductory course	8	99	Fall 2017-Spring 2018
One-semester first-year EWB Challenge design course	8	118	Spring 2017-Spring 2018
Engineering students who will be studying engineering abroad with a university abroad for a semester or more	10	-	Spring 2017-Spring 2018
Engineering students undertaking a short-term (3 weeks) three-credit study abroad program in Costa Rica and China	8	-	Spring 2017-Spring 2018
Engineers Without Borders USA chapter students	10	-	Fall 2017-Spring 2018

Measures.

There are three measures being utilized in this study; the first is a demographics questionnaire that all students being interviewed or undertaking the full survey instrument were asked to complete. This demographics questionnaire asked the participants for their age, gender, racial/ethnic background, citizenship, and current engineering major as well as if they have lived, done community service, or studied abroad or are involved with Engineers Without Borders USA or another international engineering service organization. For details of the demographics questionnaire, please see Appendix A. The second, survey instrument, the Engineering Global Preparedness Index (EGPI) instrument, (Ragusa, 2011) was developed as part of a multi-university effort to develop a quantitative measure to study engineering students' preparedness for global workplaces and contains four constructs of global preparedness—engineering ethics & humanitarian values, global engineering efficacy, engineering global-centrism, and engineering

community connectedness—along with a further section focused on the professional skills appropriate to global engineering preparedness. Please see Appendices B and C for this instrument.

Finally, a semi-structured interview protocol was adopted and adapted from a similar mixed methods study utilizing the EGPI instrument and conducted at three collaborating institutions in the United States (Streiner et al., 2015). The semi-structured interviews utilized the following questions from the Streiner et al. (2015) study:

- Why did you choose to study engineering (and to go to <country or class/program>)?
- Did the <class or program> change the way you think about engineering?
- Did this <class or program> affect your thinking about the cultural relevance of engineering?

One additional question was added to the protocol to match the aims of this study:

Do you think your <class or program> has had any effect (positive or negative) on your non-technical engineering skills, such as teamwork, communication, leadership, or global and cultural adaptability?

Table 4 demonstrates how these questions are related to the overall research questions for the study and in which article they are reported.

Table 4

Research Questions mapped to interview questions

Research Question	Article	Interview Question Associated
What professional skills and global competencies for engineering graduates are recognized as fundamental by key stakeholders in global engineering practice and engineering education?	1	N/A
From the literature, what are the current educational practices and models for developing global preparedness and relevant professional skills through the undergraduate engineering core curriculum and optional or cocurricular classes and programs?	1	N/A
What, if any, differences are there between a globally oriented project (EWB) and a traditional introductory course on the development of global preparedness and professional skills over a one-semester first-year civil and environmental engineering course?	2	<p>Did the <class or program> change the way you think about engineering?</p> <p>Did this <class or program> affect your thinking about the cultural relevance of engineering?</p> <p>Do you think your <class or program> has had any effect (positive or negative) on your non-technical engineering skills, such as teamwork, communication, leadership, or global and cultural adaptability?</p>
Comparatively, how do engineering students at a mid-sized, western U.S. university reflect on the effects of different domestic and global curricular and cocurricular classes and programs on their engineering global preparedness and professional skills??	3	<p>Why did you choose to study engineering (and to go to <country or class/program>)?</p> <p>Did the <class or program> change the way you think about engineering?</p> <p>Did this <class or program> affect your thinking about the cultural relevance of engineering?</p> <p>Do you think your <class or program> has had any effect (positive or negative) on your non-technical engineering skills, such as teamwork, communication, leadership, or global and cultural adaptability?</p>

Procedure.

This study utilized three different procedures. The first procedure outlined was to collect data through the EGPI survey instrument in multiple sectors of two first-year civil and environmental engineering design classes. The second procedure was designed to recruit through email and interview in person engineering students who had studied abroad or had taken one of the first-year civil and environmental engineering design classes. The final procedure was designed to recruit in person, for interviews, engineering students who are members of the University's Engineers Without Borders USA student chapter, students who had studied engineering abroad for a semester or more, and those that had undertaken short-term faculty-led study abroad programs at the mid-sized, western U.S. university. The students were interviewed and audio-recorded, following an adapted version of the semi-structured interview protocol validated by Streiner et al. (2015). Demographical data from participants were also collected, with the method drawn from the EGPI.

The quantitative data were analyzed on a pre-post test and retrospective pre-test basis in SPSS to compare and contrast the relative gain in both classes while examining subgroups such as gender, race, and international experience level. The interviews were transcribed in Nvivo and analyzed using the Qualitative Content Analysis (QCA) framework (Roberts, 2000), through which the transcribed data were coded for:

- 1) the constructs contained within the EGPI for triangulation purposes
- 2) key constructs from the structured literature review
- 3) codes and themes that emerged from the coding process.

From this, three articles were developed. The first article is based on a structured analysis that developed an understanding of the professional skills global engineers need and

what are the best practices for teaching them in undergraduate engineering programs. The second article will compare students' self-assessment of global engineering preparedness by comparison of two different global design contexts in undergraduate engineering design classes. The third article will use students' narratives collected through interviews to compare and contrast engineering students' experiences and global preparedness based on different curricular and cocurricular classes and programs in engineering.

The research procedures were designed to be compliant with the U.S. Department of Health and Human Services Code of Federal Regulations, 45 CFR § 46.102(2009), and were fully approved by the university's Institutional Review Board from the start of the study in August 2016 until the study closed in June 2018. The study was deemed to have minimal risk to participants, and the approval notices are in Appendix D.

The process model in Figure 5 develops the procedural framework for this study, bringing together quantitative and qualitative data drawn from the students engaged in the five different engineering classes and programs, along with the analysis of the literature, to present the three articles within this study.

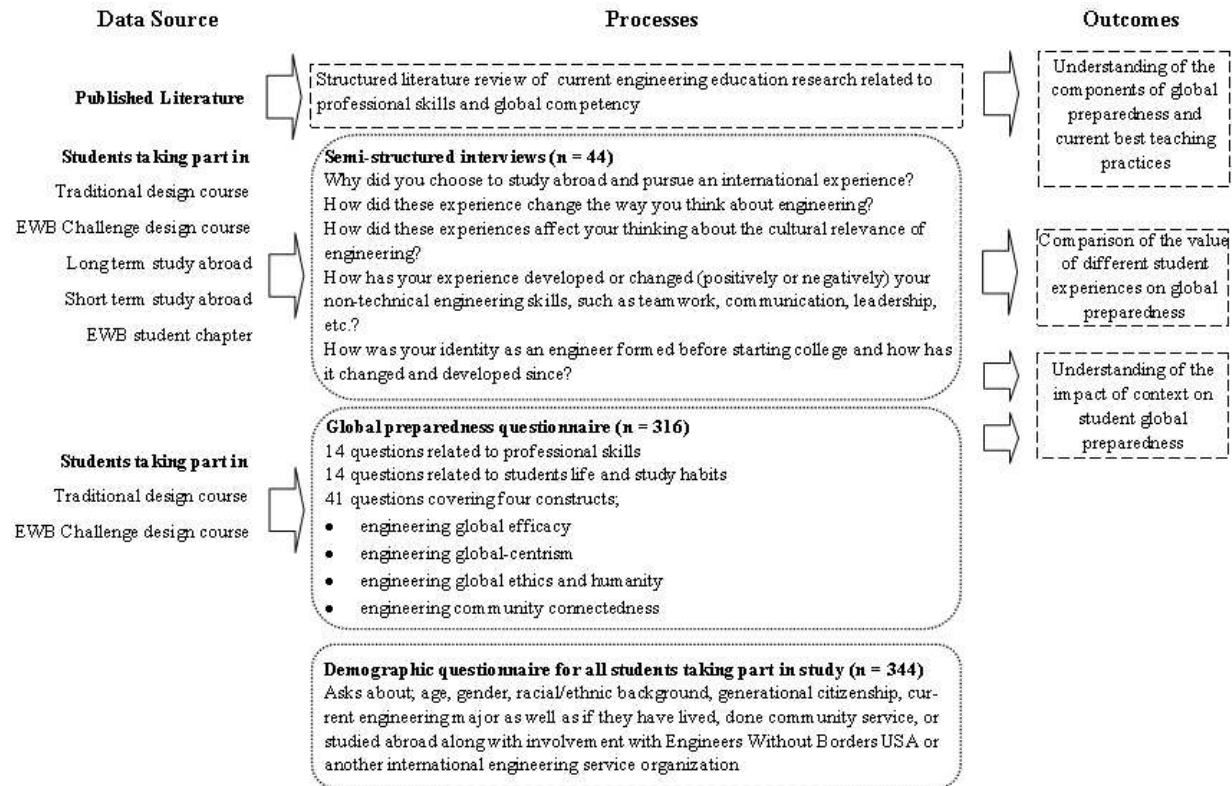


Figure 5. Process model overview of this study

Appropriateness of the Research Design

The goal of the study is to produce knowledge that may be generalizable within similar contexts, about different engineering design project formats from reflections of students, that may, if appropriate, be used by engineering instructors to change how engineering design is taught. Critical reflection throughout this study is central, given that engineering and engineering education are shaped by social, political, cultural economic, ethnic, and gender values that have crystallized over time (Guba, 1990) to become the practice of engineering and the methods and culture of engineering education today. It is equally essential that the participants' voices, rather than the researchers', are foremost, to support the external validity of the research and give the participants an advocacy voice. Providing their voices requires the quantitative data in this mixed methods study to act as a support and scaffold to the reflections of

the participants, supported by findings from peer research studies (Guba, 1990) and interviews with the students. As such, the methodology can be defined as correlational and case-controlled, as the research explores the differences among students who have undertaken five different engineering classes and programs (Gliner et al., 2009).

Limitations of the Study

There are limitations within this study that affect the potential impact and generalizability of the results. Firstly, in the engineering college of the mid-sized, western U.S. university in which this study takes place, 22% of students in the Fall 2017 first-year student intake identified as female, and 75% of the students identified as white, while 66% of the intake were in-state students, i.e., were resident in the same state as the university before enrollment and were not international students (Institutional Research Planning and Effectiveness, 2017). This creates a socio-economic context that may be particular to engineering colleges with similar demographics and geographic location, which may affect the students' global awareness, through their interaction, or lack thereof, with global issues, travel, people, and language. More specifically, all the students included in the quantitative section of this study came from the Department of Civil and Environmental engineering which has slight but significant differences regarding demographics from other departments within the College of Engineering, as the department with the highest ratio of self-reporting female to male students. Also, many of the engineering students interviewed for this study identified civil and environmental as the engineering discipline in which it is easiest to translate engineering to its effect on people and the environment. Potentially, it may, therefore, be that civil and environmental engineering students naturally identify more readily with and value professional skills and global preparedness, so results may not be transferable to other engineering disciplines.

The groups included in this study, particularly those that were part of the qualitative data collection, highlight a potential non-probability sampling issue, in that the students who volunteered to interview were probably those most interested in the subject matter and are, therefore, more likely to be biased toward reflecting positively on global preparedness and professional skills. While this bias may be more evident in the groups of students who had chosen to study abroad or volunteer as part of the Engineers Without Borders student chapter, the students from the other groups may also hold these ideas in higher regard than their peers who chose not to volunteer to be interviewed.

Researcher Positionality

It is important that this research reflect the experiences of the students engaged with the study, and so the researcher should explicitly express his positionality and intersectionality as relates to the students' differing experiences (Forst & Elichaooff, 2003; Harding, 2006; Olesen, 1994) in order to clarify the researcher's role and biases within the research. This framing is particularly critical for a study that includes an international component and, as such, reflects on the power dynamic between western countries and postcolonial developing countries elsewhere in the world (Harding, 2006; Jaggar & Wisor, 2014). The researcher's prior experience as an activist within engineering education has led to an anti-realist constructivist ontological positionality; this is demonstrated through an understanding that there is no absolute truth, but that this research is based within the context in which it was undertaken and is subject to the norms not only of that context but also of the students whose voices are contained within the study. As such, this research provides an understanding of a contextualized reality, based on those student voices, that may be useful and generalizable to others in similar situations in the creation of engineering education curricula and programs.

Ethical Considerations

Other than the requirements set by the University's IRB, Bryman and Bell (2007) compiled the following list of ethical considerations by analyzing the published guidelines of nine professional social sciences research associations.

- Research participants should not be subjected to physical or psychological harm in any way whatsoever.
- Respect for the dignity of research participants should be prioritized.
- Full consent should be obtained from the participants before the study to ensure voluntary participation.
- The protection of the privacy of research participants must be ensured.
- An adequate level of confidentiality of the research data must be ensured.
- The anonymity of individuals and organizations participating in the research must be ensured.
- Any deception or exaggeration about the aims and objectives of the research must be avoided.
- Affiliations in any forms, including sources of funding, as well as any possible conflicts of interests, must be declared.
- Any communication about the research should be done with honesty and transparency.
- Any misleading information, as well as representation of primary data findings in a biased way, must be avoided.

Based on these guidelines, it was fundamental to the study design to ensure participants' voluntary and anonymous involvement in the study, particularly given that many of the participants were taking or have previously taken classes taught by the dissertation co-advisors

and committee members. Due to this, the study was developed to give students not only complete anonymity during publishing but also anonymity from all (people), with the exception of the author, throughout the data collection and analysis stages. To this end, when participation in the questionnaires was requested in classes taught by the advisors or committee members, they left the room and did not return until after the data were collected. Student ID numbers were collected to connect the pre- and post-questionnaire responses. However, these were coded within the data sets, and the only copy of the codebook was kept in a secure, password-protected drive that is physically and electronically inaccessible to the instructor for the two classes. The confidentiality of this data will continue to be maintained and identifying data has not, and will not, be made available. Likewise, digital audio recordings from interviews were similarly stored, with only anonymized transcripts with identifying data redacted (including names and countries) made available to advisors and committee members, as per the IRB protocol. No deception or other non-transparent methods were utilized during data collection, and the interview question set, along with the IRB consent, were shared with each interviewee before their interview. In accordance with the mid-sized, western U.S. university's dissertation guidelines, all work from other authors has been credited following the American Psychological Association 6th Edition format (American Psychological Association, 2010) and a full list of references is available at the end of each chapter. The next section will discuss possible internal and external credibility and validity issues and the steps taken to ensure the objectivity of this research.

Internal and External Validity

Within the qualitative portion of this research, the research legitimization model proposed by Onwuegbuzie and Leech (2007) was utilized to identify and manage threats to external credibility and internal validity. This model, shown in Figure 6, was used to integrate the many different facets of validity recognized by qualitative researchers.

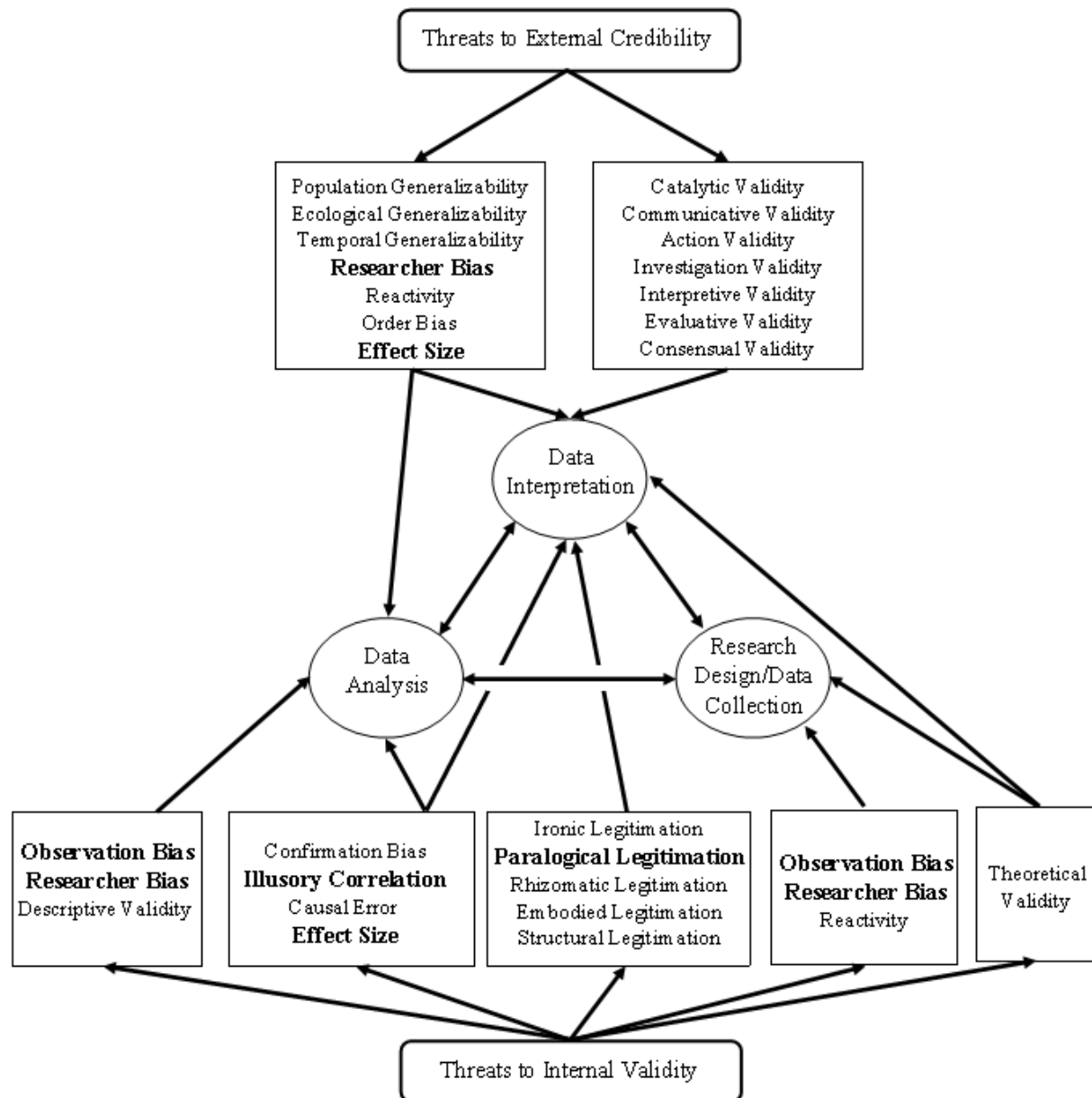


Figure 6. Qualitative Legitimation Model with threats applicable to this study highlighted. Adapted from *Validity and qualitative research: An oxymoron?* A. Onwuegbuzie & N. Leech, 2007, *Quality & Quantity*, 41(2). Copyright 2006 by Springer

Utilizing this framework as a guide, the researcher determined that the relevant threats to the internal credibility and external validity of this research are observational bias, active and passive researcher bias, illusory correlation, paralogical legitimation, and effect size. The threats and methods taken to manage or alleviate the threat are outlined below.

- Observational bias deriving from having collected insufficient data from study participants to construct findings (Lincoln, 1985) was a concern, particularly for the engineering students who have undertaken a short-term (3-week) study abroad program in Costa Rica and China and EWB-USA Student chapter members, given that there are only a small number of engineering students who have undertaken these classes and programs. Through the researcher's recognition of this issue before data were collected and sensitivity to this limitation to the design and data, the researcher has controlled this bias by combining smaller groups that had been initially proposed into the five groups included in this study.
- Active researcher bias required management in this study given the deep engagement the author has had with Engineers Without Borders and, specifically, the Engineers Without Borders Challenge as described earlier in the researcher positionality statement. To this end, the advisor and some of the committee members were requested to check the procedures and analysis of the data, given that they did not have any conflicts of interest with regards to the EWB Challenge. For full clarity, the co-advisor is the instructor for CIVE103, the class in which the EWB Challenge is taught at the mid-sized, western U.S. university, and one member of the committee was an advisor of the pilot project of the EWB Challenge in the United Kingdom. They were not asked to oversee the procedures and analysis.

- Passive researcher bias about gender within discussions with female engineering students was also a concern. To empower the participants, potential bias was managed by structuring the interviews such that any reflections on the gendered nature of engineering were not asked until after trust had been built. Explicit permission was required, with the interviewer briefly describing the theoretical framework of engineering identity authorship and widely identified gender differences (Society of Women in Engineering, 2017; Wang & Degol, 2013) before asking for permission to ask questions related specifically to gender.
- Illusory correlation was an issue that required recognition during the study design, given that the researcher experienced an engineering undergraduate experience in the United Kingdom and not the United States undergraduate engineering experience of which the participants are part. This false confirmation bias (Onwuegbuzie, 2000) may have led to the researcher seeing the participants' experiences through the bias of his own experiences and so assuming during data interpretation that the students would draw the same meanings as the researcher due to their similar, but not identical, college experiences, which are also separated by over ten years.
- Paralogical legitimation was a possible threat to this research, given that design of the research was to uncover paradoxes that exist within the groups investigated as alternatives to the norm of engineering teaching and identity and, as such, these paradoxes and the heterogeneity of the findings could be emphasized over confirmatory or normal findings. The findings could also reach the levels of *voluptuous legitimation*, in that the researcher, without recognition of the boundaries of the research, could have used the atypical (for engineering education) situation of the investigated groups to

develop analyses that are described as generalizable but are, in a practical sense, not generalizable (Lather, 1993).

- Effect size is an issue that was considered given that two of the groups (for the quantitative portion of the study) are magnitudes larger than the size of the qualitative interview groups. Designing this study as a three-article dissertation allowed for the data to be utilized in two different configurations; first, the qualitative interview data could be compared within and between groups of similar size and the second configuration allowed for the quantitative data for two of the groups to be added to and deepened through interviews drawn from the larger quantitative group.

Summary

This chapter describes the research design and justifications utilized for this study; it outlines the philosophical and practical reasoning for choosing a correlational case-study design for this study, based on the five study groups and the desire to uncover differences among the different groups about the experiences they have undergone. This mixed methods study will utilize interviews with students undertaking the five different treatments—curricular and cocurricular classes and programs—supported, where practicable, by quantitative data. Through this design, the student voices, their opinions, and reflections on the different models were paramount, and threats to validity and credibility were managed through the use of participant checking and careful management of processes to ensure full honesty and confidentiality in data collection, analysis, and reporting.

The following three articles focus on reporting different facets of the research, followed by a concluding chapter that brings the facets together into a cohesive outcome.

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Article 1: Structured Review of Global Engineering Preparation for Undergraduate Engineering Students in Engineering Education.

Introduction

There are two main motivations for developing globally prepared engineering students, firstly, the engineering profession is increasingly seeing global and cultural adaptability as fundamental to engineering, and secondly, engineers who are prepared to work globally are central to the success of global development. Industry in particular sees global and cultural adaptability as a fundamental ability for engineers (American Society for Engineering Education, 2013). Patricia Galloway (2007), former president of the American Society of Civil Engineers, writes,

A solid understanding of globalization is key to an engineer's success in today's global society. Globalization involves the ability to understand that the world economy has become tightly linked with much of the change triggered by technology; to understand other cultures, especially the societal elements of these cultures; to work effectively in multinational teams; to communicate effectively—both orally and in writing—in the international business language of English; to recognize and understand issues of sustainability; to understand the importance of transparency while working with local populations; and to understand public policy issues around the world and in the country in which one is working. It will be these fundamental capacities that will enable 21st-century engineers to develop into professionals capable of working successfully both domestically and globally, highly respected by the general public and regarded...the world over as professionals of the highest order. (Galloway, 2007, p. 12)

A recent study of 80 different U.S. engineering companies (Gregg, 2011) showed that they recognize global competency as necessary given that an engineer's technical competencies and global and cultural competency has been recognized by nationwide studies in the United States, United Kingdom, and Australia as being central to the future of engineering (American Society for Engineering Education, 2013; Bourn & Neal, 2008; King, 2008; National Academy of Engineering, 2004). Teaching to these competencies in engineering is slowly being recognized by engineering education and engineering colleges as central to engineering education of the future as James Duderstadt (2009), former president and dean of engineering at the University of Michigan, Ann Arbor, stated,

It is important to stress the importance of a global perspective for engineering practice.

Key is not only a deep understanding of global markets and organizations but the capacity to work in multidisciplinary teams characterized by high cultural diversity while exhibiting the nimbleness and mobility to address rapidly changing global challenges and opportunities. (Duderstadt, 2009, pp. 45-46)

Secondly, engineers are central to international development. Each of the Sustainable Development Goals (United Nations, 2016) has an infrastructural/engineering component, from clean water needed to promote health; to transport infrastructure to support trade and economic growth; to reliable and clean energy to allow students to study and economies to function; to genetically engineered seeds to increase crop yield and allow families to be self-sufficient. These hurdles to development exist in different forms in almost every developing country. Although funding and aid have been poured into development in an attempt to address these issues, an underlying problem is the ratio of engineers to the general population. In contrast to the United States, where the ratio is 1:100, the lowest ratio in the African continent is 1:4800 in

South Africa and the ratio varies, reaching 1:170,000 in Swaziland (Matthews, Ryan-Collins, Wells, Sillem, & Wright, 2012). Without the technical expertise and capacity to develop infrastructure, developing countries cannot work toward a sustainable future where they can be free of the necessities of aid and external support.

Worldwide, engineering also has recruitment issues. UNESCO (2010) estimated that around 2.5 million new engineers and technicians would be needed in sub-Saharan Africa alone if the region were to achieve the United Nations Millennium Development Goals (United Nations, 2015) of improved access to clean water and sanitation (these goals were the predecessor to the current Sustainable Development Goals or SDGs). Without the technical expertise and capacity to develop their infrastructure, developing countries and communities cannot achieve the SDGs and approach a sustainable future in which they can be free of the necessities of aid and external support (Wong, 2016). In most cases, temporary gains in engineering capacity are created by bringing in engineers from other countries. However, because engineers are traditionally trained within the contextual framework of the nation-state to prepare them to be engineers in their local context and country (Ravesteijn & DeGraaff, 2003), their skills and knowledge may not be appropriate for the context of the other country or community. To overcome this barrier, engineering needs to promote itself as able to respond to complex, global and local problems, to become more socially responsible, and to link to ethical issues related to development (United Nations Educational Scientific and Cultural Organization, 2010).

In engineering, global engineering competency can be seen as inhabiting three dimensions of technical, professional, and global domains, which contain the skills and attributes of a globally competent, professional engineer (Allert, Atkinson, Groll, & Hirleman, 2007).

There is a significant issue with this generally accepted conceptual model, as it models the three dimensions as separate and disconnected, which is often reflected in how professional and global competency is taught in engineering education. This issue stems from the history of how engineering education has defined these three areas of competence. Allert et al. (2007) describe that professional skills and competencies were defined in response to the increase in design and product development as an emerging requirement of engineers, as separate to the core science and math competence needed for purely technical engineering. As globalization has accelerated, similarly a need for globally competent engineers has emerged, to which engineering education has responded with the global competency dimension displayed in Figure 7. While this study recognizes this issue, given that this conceptualization of engineering global competency is widely recognized in theory and practice, this study is structured to reflect that these areas of competency are generally defined separately. The outcome of this separation is however, that often the areas are taught separately, with professional skills classes or engineering communication classes being taught separately from the engineering technical core.

Teaching the technical dimension of engineering competency is well understood within engineering educational literature, and this structured review is an attempt to develop a greater understanding of the need for, and ways of teaching or embedding learning toward competency in the other two dimensions of the model shown in Figure 7, namely the professional and global competencies.

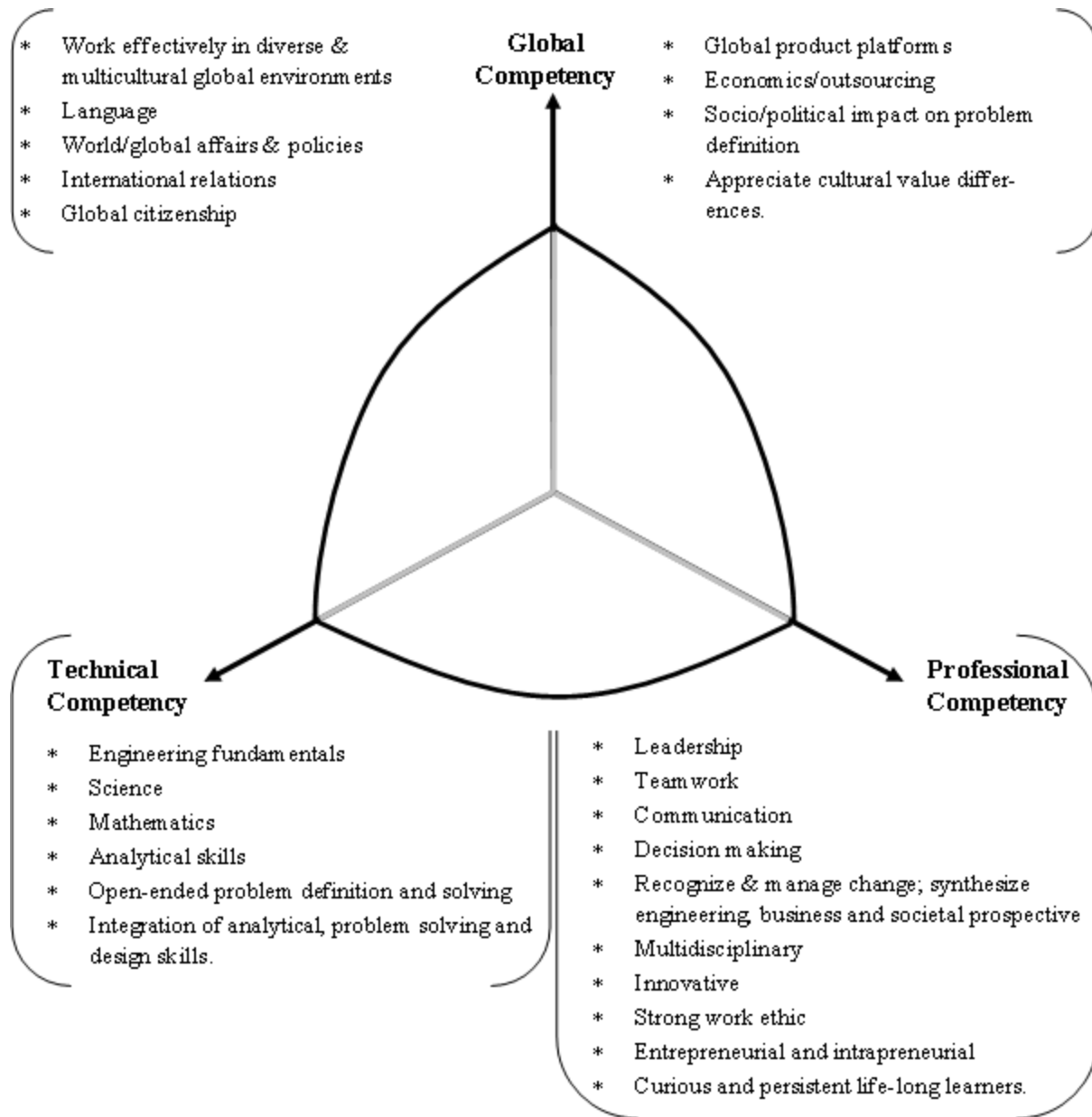


Figure 7 Attributes of the global engineering professional are conceptualized in a three-dimensional space consisting of technical, professional, and global domains. Reprinted from *Making the case for global engineering: Building foreign language collaborations for designing, implementing, and assessing programs*, B.I. Allert, D.L. Atkinson, E.A. Groll & E.D. Hirleman, 2007, *Online Journal for Global Engineering Education*, 2(2). Copyright 2007 by the University of Rhode Island

Systematic reviews in engineering education are a relatively new methodology, and typically, the process is to search for applicable studies and their written reporting, to apply inclusion criteria before evaluating the quality of the studies and then analyzing the results from

the studies in an attempt to synthesize the studies into a greater understanding (Borrego, Foster, & Froyd, 2015).

Research Questions

It is essential to understand which professional skills and global competencies are valued by stakeholders such as instructors, students, and engineering practitioners/industry and how they are taught within and outside engineering education around the world, which leads to the following research questions:

- What professional skills and global competencies for engineering graduates are recognized as fundamental by key stakeholders in global engineering practice and engineering education?
- From the literature, what are the current educational practices and models for developing global preparedness and relevant professional skills through the undergraduate engineering core curriculum and optional or cocurricular classes and programs?

Search Method

The search method utilized to examine the engineering professional skills and global engineering competencies also provides this studies response to the first research question, outlining the professional skills and global competencies recognized as fundamental by the key stakeholders in global engineering practice and engineering education. The process outlined by Borrego, Foster, and Froyd (2014) was followed to define search terms and boundaries/limitations on the search and having conducted the search within those bounds, to assess the resources found for quality.

Engineering professional skills.

The initial list of search terms for engineering professional skills was drawn from six sources. Massachusetts Institute of Technology and Harvard University recently examined the professional skills seen as required to be a professional engineer in engineering education literature and checked this list by asking their alumni now in engineering management roles to validate the skills (Fisher, 2014). In the United Kingdom, a publication by the Institute of Education and Engineers against Poverty highlighted the skills required to be a globally competent engineer (Bourn & Neal, 2008), and in Australia, the Australian Council of Deans examined the competencies they believe the engineer of the 21st century requires (King, 2008). The American Society for Engineering Education also collected student, parent, faculty, and industry perspective on professional skills for engineers (American Society for Engineering Education, 2013) and faculty, the competencies needed (American Society for Engineering Education, 2018) as part of their Transforming Undergraduate Engineering Education project (TUEE). Finally, a recent systematic review of articles related to the competencies needed for engineering practice found 52 studies since 2000 (Passow & Passow, 2017). The findings from these six studies are consolidated as shown in Table 5 – for clarity, competencies with lower levels of consensus are not displayed in this table.

Table 5

Engineering industry recommendations for professional skills to be taught to engineering undergraduates, organized by three areas of engineering competency - technical professional and global (Allert et al., 2007)

Engineering Competencies with general agreement between the six global studies	Validated through supervisor interviews (Fisher, 2014)	Engineers of the future (King, 2008)	Global engineering skills (Bourn & Neal, 2008)	TUEE - Skills (American Society for Engineering Education, 2013)	TUEE – Competencies (American Society for Engineering Education, 2018)	Systematic Review of Engineering Practice Competencies (Passow & Passow, 2017)
The country study focused on	U.S.	Australia	U.K.	U.S.	U.S.	U.S.
Technical competency						
Disciplinary knowledge	×	×	×	×	×	×
Critical thinking	×	×	×	×	×	
Problem-solving	×		×	×	×	×
Professional competency						
Ethics		×	×	×	×	×
Teamwork	×	×	×	×	×	×
Written communication	×	×	×	×	×	×
Innovation and enterprise ¹			×	×	×	
Interpersonal communication	×	×		×	×	×
Management	×		×	×	×	×
Leadership ¹		×	×	×	×	
Public speaking	×	×	×	×		
Global competency						
Cross-cultural skills	×	×	×	×	×	×
Civic responsibility		×	×		×	×
Global awareness	×	×	×			×

¹ skills added from The Global Engineer (Bourn & Neal, 2008)

Of these thirteen skills recommended by three or more of these six reports, three (disciplinary knowledge, critical thinking and problem solving), are contained with the technical competency dimension of the Allert et al., (2007) model, not the professional or global dimensions and so are not included in this study. Further removing those competencies such as global awareness, civic responsibility and cross-cultural skills which are related to the global competencies that are covered in more depth later in this article, the remaining professional competencies can be further consolidated into six thematic areas of competency: ethics, leadership, innovation and entrepreneurship, communications (interpersonal and written communication, public speaking), teamwork, and project management. As can be seen in Table 5, there is general consensus in the U.S., and in western engineering education on the areas in which engineering students need to gain professional competency, however there are still differences in the details of the knowledge, skills and abilities contained within those competencies, although the recent publication from the TUEE project highlights the American Society for Engineering Education's work to develop consensus around these details (American Society for Engineering Education, 2018).

Global engineering competencies.

Recently there has been a significant level of research activity focused on the concept of globally competent engineers, and as part of exploring the rationale for teaching globally competent engineers (Parkinson, 2009), another set of attributes for the globally competent engineer was created. Brigham-Young University's Mechanical Engineering Department worked with their alumni in 48 states and 17 countries to develop their set of global competencies (Gregg, 2011). Drawing on this previous work, the American Society of Engineering Education's Special Interest Group on International Engineering Education

collaborated with the International Federation of Engineering Education Societies (IFEES) and the Global Engineering Dean's Council (GEDC) to develop and implement a survey instrument to validate the attributes they saw as essential to a globally competent engineer (Huntley, 2014).

Table 6 synthesizes the findings from these different research projects to demonstrate the necessary skills and attributes for the globally competent engineer.

Table 6

Synthesis of the skills and attributes of a globally competent engineer

Skills and attributes of the globally competent engineer (Allert et al., 2007)	Allert (2007)	Parkinson (2009)	Gregg (2011)	Huntley (2014)
Ability to work effectively in diverse and multicultural global and transnational environments	X	X	X	X
Language skills	X	X	X	X
Understanding of world/global affairs & policies	X	X	X	
Understanding of international relations	X		X	X
Global citizenship	X	X	X	X
Knowledge of global product platforms	X	X		
Understanding of economics/outsourcing	X	X		X
Understanding of the socio/political impact on problem definition	X	X		X
Appreciation of cultural value differences	X	X	X	X

The conceptualization of engineering global competency is not as complete as it is for professional competency in engineering. While there is general agreement from industry, professional bodies and faculty that preparing engineers to work globally is important to the future of engineering as can be seen from the inclusion of cross-cultural skills, civic responsibility and global awareness in Table 5, there is less consensus in the details of what this means for engineering education. As such, Table 6 can be seen as a guide for this study, along with Ragusa's (2011, 2014) conceptualization of global preparedness as preparing engineering students for global workforces in terms of their preparedness in communication, professional

ethical responsibility, understanding of global issues and lifelong learning in differing global contexts and cultures. It should also be highlighted that the definition of global competency used for this study is a United States encultured definition of global engineering competency and isn't seen as a 'global' definition. There are differing methods and conceptualizations of how competency is defined in differing fields and countries (Bristow & Patrick, 2014; Westera, 2001) however, Olson and Kroeger (2001) found general agreement in the content of definitions of global competency around the world, despite the different approaches and conceptualizations of competency.

Inclusion criteria and search strategy.

After developing these two lists of key search terms in Table 5 and Table 6 used in the initial review, further bounding criteria were set for the full search: the publication date must be within the last five years to ensure that the results are recent; the research should focus on undergraduate programs, given the difference between graduate and undergraduate programs and their students; the study should be written in English (or be bilingual, with one of the languages being English); and the studies should be published in recognized journals or academic magazines. Based on Borrego et al. (2015) work on developing an understanding of systematic reviews in engineering education, the most utilized search strategies employed are searching bibliographic databases and journal titles. Web of Science and IEEE Explore are two of the top ten databases utilized by engineering education researchers undertaking literature reviews so these, along with the American Society of Engineering Education's Journal of Engineering Education, the International Journal of Engineering Education, and the European Journal of Engineering Education were included in the study. The full search strategy and results are outlined in Figure 8, demonstrating that from over 9,000

articles, by their title and abstract, 196 articles were selected based on their titles and abstracts for the second stage of the search (some articles were present in both searches), which involved thoroughly reading the articles and coding them by the key terms.

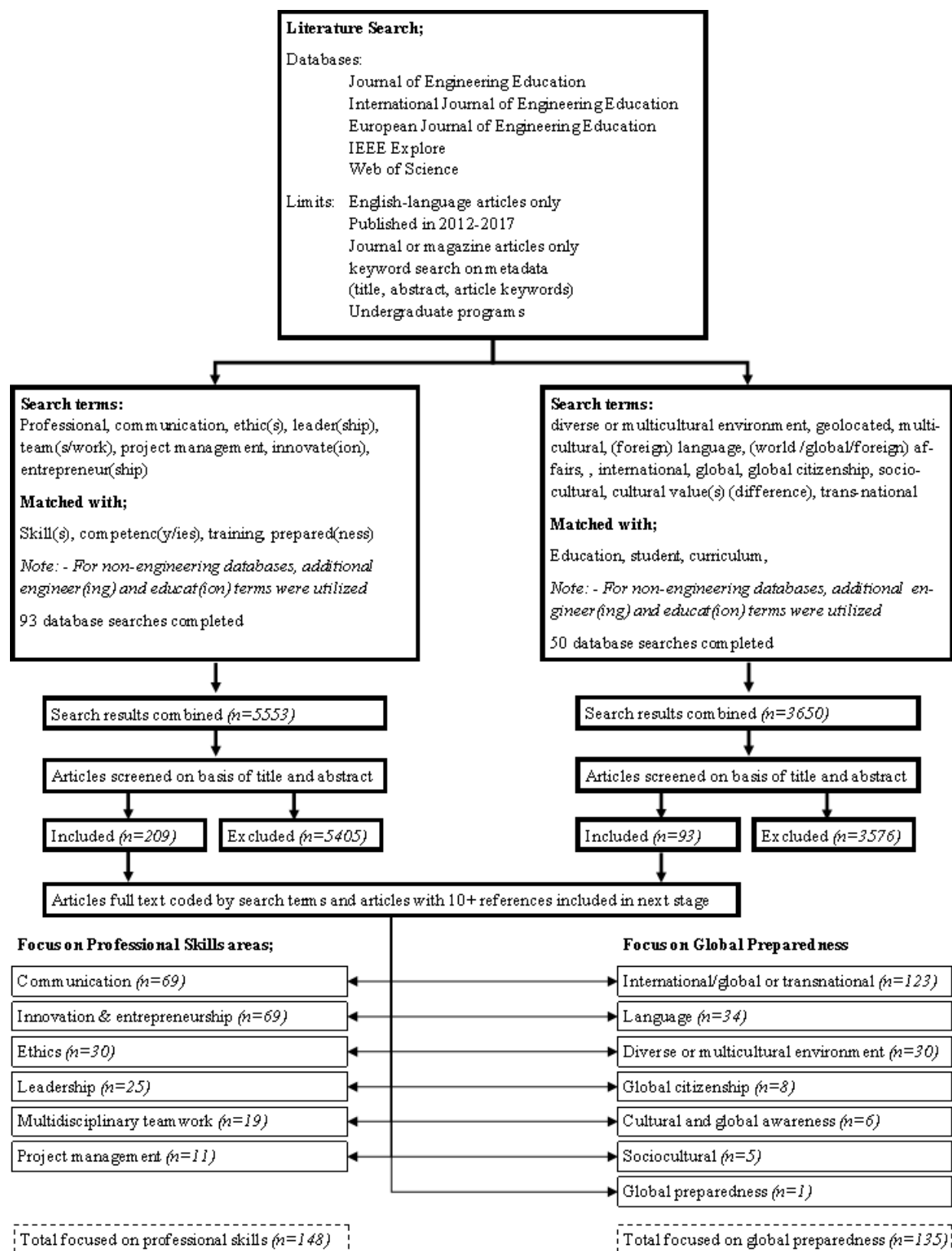


Figure 8. Flow diagram of the literature review process highlighting the number of resources identified, included, and excluded through the initial search and sorting process

Limitations.

While several attempts were made to include different spellings or conjunctions of words and to include all potential suffixes, it is likely that some studies were not identified by the search. There are inherent biases created by searching in English and only including English language or bilingual articles, as is demonstrated by the high number of studies that are located in the United States, Western Europe, and Australia. A limitation of the scope of this study is that it is designed as a review of engineering education literature and was not designed to include literature from the other STEM fields, or indeed educational literature in general (other than those studies included as comparisons from non-engineering fields) which may be relevant or transferable to engineering education. Also through the selection of three journals and two databases, some relevant journals may not have been included within the parameters of the search.

Analytical Methods

Methodological quality of included studies.

There are, unfortunately, no current tools for assessing the methodological quality of cross-sectional, qualitative or quantitative studies based on surveys, ethnographic observations, or interviews (American Educational Research Association, 2014). As such, this study utilized the quality framework suggested by Passow and Passow (2017) in their systematic review of the competencies engineering programs should emphasize.

- Comparison group - Did the study design utilize comparison groups to compare learning or teaching situations that are subject to the treatment with similar situations that are not treated?

- External Observation - Were the engineering students or treatment observed as part of the study, or did the study design rely on self-efficacy and other self-reported data?
- Detailed Accounts - Was the study holistically reported, i.e., did it contain detailed accounts of the experience/situation based on external observations and other methods?
The rationale for this is to correct for self-reporting bias within individuals' responses (Walther, Kellam, Sochacka, & Radcliffe, 2011; Walther, Sochacka, & Kellam, 2013).
- Validated Measures - If survey instruments were utilized as part of the study, does the instrument have content validity to the study and do the questions have construct validity insofar as they measure what is intended?

For inclusion in this study, three or more of these standards must be met; where appropriate, structured reviews were also included if they met these criteria.

Procedures

After the initial search procedure was completed, the 238 articles (some were found in both the professional skills and global competency searches) identified by abstract and title were re-read and coded by the key terms while also being tested against the methodological quality framework presented by Passow and Passow (2017). This process reduced the number of articles included in the study to 94; the number of articles per code are outlined in Table 7. Please note, articles may be included in one or more codes and may also be included in both the professional skills and global preparedness theme.

Table 7

Results of coding included articles by key term and methodological quality analysis

Professional Skills Theme	No. of coded articles	No. of articles with sufficient methodological quality (Passow & Passow, 2017)	Global Preparedness Theme	No. of coded articles	No. of articles with sufficient methodological quality (Passow & Passow, 2017)
Ethics	30	13	Diverse or Multicultural Environments	31	13
Leadership	25	14	Language Skills	34	10
Communication	69	20	World/Foreign Affairs	0	0
Multidisciplinary Teamwork	19	16	Global/International/Trans-national	123	51
Project Management	11	6	Global Citizenship	8	1
Innovation and Entrepreneurship	69	16	Cultural Value Differences	0	0
			Cultural and Global Awareness	6	3
			Socio-cultural	5	3
Total	148	64	Total	135	53

The articles included in each code were synthesized and reported on by professional skill or global preparedness theme and appear in the following results section. Due to the relatively low number (for some themes) of articles available and the global reach of the search, this analysis is completed on a realist synthesis (Pawson, 2006); recognizing the differing contexts of the studies included, this also enables the inclusion of both quantitative and qualitative studies to create a more holistic understanding of each theme. Additional articles were selected from non-engineering fields to provide comparisons from other fields.

Results

This results section, as a response to the second research question develops a deeper understanding of the current educational practices and models for developing the global competencies (as aspects of global preparedness) and relevant professional skills found through the search process developed for the first research question.

Professional skills themes.

Professional competencies have been increasingly seen by industry as fundamental to practicing engineering (Ahmed, Capretz, & Campbell, 2012; Passow & Passow, 2017). Despite calls from industry (American Society for Engineering Education, 2013), and the professional bodies that represent engineering (National Academy of Engineering, 2004, 2005) to increase the focus on professional competency development in engineering degree programs, engineering colleges are struggling to meet these expectations (Aničić, Divjak, & Arbanas, 2017; Berglund, 2015). Engineering colleges are also struggling to change the culture of instructors and some students to recognize the importance of engineering professional competency (Fletcher, Sharif, & Haw, 2017; Itani & Srour, 2016). A recent study surveyed over two thousand alumni of a large public Midwestern university to discover which ABET competencies (Accreditation Board for Engineering and Technology, 2016) they find most important to their work as practicing engineers. The study found that multidisciplinary teamwork was the most essential skill, closely followed by data analysis, problem-solving, and communication. Ethics and life-long learning both ranked higher than design and engineering tools, closely followed by contemporary issues and global/societal impact related to cultural and global adaptability and global preparedness (Passow, 2012). Other studies have made similar findings, with multidisciplinary teamwork, ethics, and communication consistently being found as the most important skills (Wankat, 2017).

Wankat's study found that these skills should be taught in tandem with, rather than in isolation from, technical skills (Passow & Passow, 2017). Teaching these skills in tandem would overcome students and some instructors reluctance to teach or learn 'soft skills' that they may feel, despite the push from industry and the professional bodies, are not as important as technical engineering competency to engineering practice and so, to the students learning (Itani & Srour, 2016). Integrating professional competency learning through existing courses also removes the significant barrier of adding an additional course to engineering students course load requirements for their degree program (Silbey, 2015) and can be done without reducing students mastery of their engineering technical competencies (Stawiski, Germuth, Yarborough, Alford, & Parrish, 2017).

Ethics.

Finelli et al. (2012) suggested that there are three constructs within engineering students' ethical development: knowledge of ethics, ethical reasoning, and ethical behavior. Their study utilized data from over four thousand undergraduate engineering students across the United States related to curricular and cocurricular ethics learning and found that 80% of the students had made unethical decisions related to their studies, revealing that discussions of academic integrity with engineering students are having little impact on their behavior. This is particularly relevant given the high number of international students in engineering colleges and their differing cultural, ethical norms (Wilson, 2013). Overall, the study found that engineering students' ethical development was deficient and that most formal ethics education in engineering is too simplistic and abstract (McCormack et al., 2012) to empower students to understand and judge complex ethics problems, despite these issues' fundamental importance to engineering practice (Byrne & Mullally, 2014). Similar challenges have been experienced in other

vocational fields. The Institute of Biomedical Ethics at University Basel, Switzerland, found that undergraduate biology and pharmaceutical students needed specialist bioethics courses to understand the complexities and depth of the ethical situations they find within their fields (Engel-Glatter, Cabrera, Marzouki, & Elger, 2018). These findings were also supported by further studies incorporating eighteen U.S. engineering colleges (Holsapple, Carpenter, Sutkus, Finelli, & Harding, 2012), taking place at an engineering university in Portugal (Monteiro, 2017), and focusing on health science educators in Norway (Kordahl & Fougner, 2017). The authors suggested that students gain more from practical cocurricular experiences, such as service learning (Fisher, Bagiati, & Sarma, 2017; Zoltowski & Oakes, 2014), and proposed strengthening this mode of learning as part of the curriculum. However, as a study at Texas A&M discovered, teaching “real-world” ethics can create more complexity for students, particularly if global contexts are utilized. Through the Texas A&M study, researchers determined that students are aware of the complexities of differing global cultures and their role in ethics and as a result the instructors decided to switch to “user-centered” course design, so that the students had to fully engage with and understand the context of the end-user, rather than thinking of the ethics of the context as ancillary to the engineering design process (Lail et al., 2013). Similarly, a study of the effect of simulation on the ethical knowledge of undergraduate nursing students found that students’ understanding of nursing ethics principles was enhanced (Donnelly, Horsley, Adams, Gallagher, & Zibricky, 2017) compared to more traditionally taught students. Case studies are a more common way to teach ethics, although this method can create ethics situations that are too simplistic for students to develop ethically and can create courses that feel separate from the core curriculum (Bairaktarova, Cox, & Srivastava, 2015). Wilson (2013) has developed a role-play scenario-based case founded on the Chernobyl Nuclear Power

Station accident, with the students having to develop and understand the decisions of the different stakeholders, such as the state, the power plant, the planet. Through development of a complicated case such as this, the students have shown high levels of ethical reasoning and behavioral development. Studies in the medical field have also demonstrated that case-based ethics learning, or simulations, help students bridge the gap between having ethical/legal knowledge and being able to act with moral integrity (Kong & Knight, 2017).

Leadership.

Stephens and Rosch (2015) used a national dataset which contained responses from over ninety-thousand undergraduate students at over 100 U.S. universities to a questionnaire on leadership to understand engineering students' leadership experience before and during college, compared to their non-engineering peers. The study found that engineering students were slightly less likely than their peers to have taken on leadership roles during high school but were as likely as their peers to do so while at university, and their self-reported leadership skills were similar. There was, however, a significant difference in their interpersonal skills (in terms of ease with interpersonal interaction, conflict management and consensus building), and the study found that engineering students do not develop these skills during university to the same level as their non-engineering peers due to the heavy credit load of most engineering programs. A further study of over five thousand undergraduate engineering students found that much of their leadership development came from cocurricular and informal learning, through student clubs, volunteer opportunities, and part-time work, due to the lack of formal training in leadership available to them through their engineering curriculum (Knight & Novoselich, 2017). Similar findings in other countries have led to the development of leadership programs for engineering students, such as the PROLIDER program, a collaboration between two leading Brazilian

universities and their industry partners. Through this program, engineering students spend part of their final year working on leadership skills and working as a trainee with one of the program's industrial partners. The students are also given funding by the program to bring expert speakers in leadership to the university, recognizing the benefit to the students of learning for experienced leadership professionals. This program has received positive feedback from the students regarding their professional and leadership development and has reduced the average number of years between students graduating and gaining a management level position in industry (Gerolamo & Gambi, 2013). Similarly, at the Massachusetts Institute of Technology, the Bernard M. Gordon-MIT Engineering Leadership Program (GELP) was created to help students gain leadership skills. In partnership with this program, a leadership module within the three-semester satellite development class was created to support the students' development of leadership and teamwork skills while they partake in a "real world" experience in which they work as a team to develop satellite prototypes. The students reported that having leadership training and mentorship available that they could directly apply to their project was invaluable and helped them to embed their leadership skills (Babuscia, Craig, & Connor, 2012). The Western University in Ontario, Canada, developed a one-week leadership program for medical students based on four themes typically found in business school pedagogy: understanding change, effective teamwork, leadership in (patient) safety, and leadership in action. However, while students responded that they enjoyed the course, they felt it was ineffective; unlike the GELP program at MIT, the medical students' program was not grounded in the healthcare context, and they did not feel the business context used was supportive to their learning (Cadieux et al., 2017), which is similar to the issue found when directly importing business curriculum into engineering programs. A further complication is that to support this style of leadership

development; educators have to “mutate” (Galli, Pino, & Suteu, 2017) from their role as an instructor delivering content to students to also be able to mentor and empower students as leaders, which can be challenging. It can also be beneficial to have students work with instructors to co-create leadership learning activities and experiences, similar to the PROLIDER program highlighted earlier. Studies of healthcare students in Canada and the United Kingdom found that including student perspectives in curricular development created a more effective and engaging program and helped the students involved to gain valuable leadership experience (Ha & Pepin, 2017; Sheriff et al., 2017). An alternative route through which many students develop leadership competency is through cocurricular programs, leading student or volunteer organizations or programs (Boulais et al., 2015; Huff, Zoltowski, & Oakes, 2016; Litchfield & Javernick, 2015).

Communication.

Communication skill is based on the ability to understand and apply the dynamics of sending and receiving both verbal and nonverbal messages (Wilkins, Bernstein, & Bekki, 2015), and in engineering education, there tend to be two different methods of teaching engineering students communication skills. One option is a course focused on professional or technical communication, taught either in the engineering school or by a communications instructor from another part of the university (Sivapalan, 2017). The second method is to integrate specific pedagogical techniques into introduction or technical/project-based engineering courses (Bodnar & Clark, 2017). As part of a third-year technical writing and business writing class taught at Northern Kentucky University, scenes from a popular, office-based situation comedy television show are utilized to help students develop communication skills through illustrating professional communication concepts. Overall, students found the “real-life” element of these illustrations

very helpful in allowing them to understand verbal and non-verbal ways of communicating (Bloch & Spataro, 2016). In a similar study with nursing students in Singapore (Shorey, Siew, & Ang, 2018), students reflected that this blended pedagogical design also helped the students to develop intra-professional communication skills, by increasing their understanding of the different stakeholders in medical situations and how to communicate effectively with each stakeholder individually. Alternatively, in an introduction to chemical product design course at a U.S. engineering college, researchers studied the effect of using communications-based games to improve students' communication skills using two different levels of treatment (Bodnar, Anastasio, Enszer, & Burkey, 2015; Bodnar & Clark, 2017). In comparison to the control group, the second group was given games-based instruction, while a third group was given games-based instruction as well as additional communication games-based instruction. Using a subset of communications questions from the National Survey of Student Engagement (NSSE) instrument (Center for Postsecondary Research - Indiana University School of Education, 2014), the study found that students reported that games-based pedagogy, and in particular, communications-based games, significantly improved their own communication skills.

With the increase in national or global virtual teams being utilized in engineering design classes, virtual or remote communication is becoming increasingly important. Several studies have focused on how to improve or support student communication through virtual platforms and the specific challenges inherent in virtual communication as this is the foremost failure point in virtual teams (Colsa, Ortiz-Marcos, Cobo-Benita, & Moreno-Romero, 2015; Dai, Liu, Morrison, & Lu, 2016; Davison, Panteli, Hardin, & Fuller, 2017; Esparragoza et al., 2015; Y. Li, Rau, Li, & Maedche, 2017). These studies reinforce the importance of face-to-face communication through video conference, rather than relying on only written forms of

communication. The studies also stress the importance of instructors' engagement with, and understanding of, the communication platforms students may choose to use, including but not limited to email; voice-over-IP applications such as Skype and Google Hangouts; video conferencing; social media applications such as Twitter, Facebook, Weibo, and WhatsApp. This is fundamental, as instructors should be supporting the students in maintaining professional communication across all platforms. An additional area of communication which is not taught very often in engineering but is becoming increasingly crucial to all vocational fields is communication of the field to the general public. A recent study at Portland State University assigned medical students to develop an infographic to convey public health information to the general public. The study found that utilizing this medium helped the students to develop visual communication skills and to be able to translate complex health issues to a more general audience, increasing the visibility and understanding of their work (Shanks, Izumi, Sun, Martin, & Byker Shanks, 2017).

Multidisciplinary Teamwork

Traditionally, in engineering, teamwork is “taught” through team projects, with the assumption being made that through the process of being on a team, students will learn teamwork skills through trial and error (Hadley, 2014). This project-based learning approach does have some positive effect on students teamwork skills (Carmona-Murillo et al., 2014), but because there is often little or no structured development of those skills, or reflection by the students on their learning, the results are not consistent. In medical education, Earnest, Williams, and Aagaard (2017) suggested a three-level pedagogical framework as shown in Figure 9 to provide structure to teaching teamwork in medical schools, which face similar issues.

This framework suggested that most teamwork learning in engineering education occurs at level one and two but does not include the explicit instruction required for level three.

Level 1	Minimal team learning	Students work in small groups, but no teamwork learning factors are present
Level 2	Implicit team learning	Students are engaged in interdependent learning activities, but there is no explicit focus on teamwork
Level 3	Explicit team learning	Instructor/facilitator creates learning environments where teams work interdependently toward common goals and are given explicit instruction and practice in teamwork.

Figure 9. Earnest et al. (2017) pedagogical classification of teamwork learning. Reprinted from *Toward an optimal pedagogy for teamwork*, M.A. Earnest, J. Williams & E.M. Aagaard, 2017, *Academic Medicine*, 92(10). Copyright 2017 by the Association of American Medical Colleges

Hadley (2014) found through a simple intervention—a three-hour session on teamwork based around the board game Pandemic—that first-year engineering students’ teamwork skills were increased to be on par with third-year engineering students who had no formal teamwork instruction and had gained their skills through trial and error. A similar intervention at the Universidad Politécnica de Madrid (UPdM) found that through a short seminar on teamwork before a planning session in which the students planned the tasks they had to perform, Computing Science Engineering students taking an Operating Systems course dramatically improved their teamworking ability, compared with students in classes that did not use these two steps (García-Martín, Pérez-Martínez, & Sierra-Alonso, 2015). Other interventions do not require changing or adding to the content of the class but have found that similar gains can be created by altering the structure of the class. Another six technical engineering courses at UPdM were altered to promote cooperative learning teams in which small groups of students are responsible for not only their learning but also that of their group through requiring the group to work together to achieve learning goals (M. P. Li & Lam, 2013). Not only was this methodology reported to be a highly satisfactory learning model for the students, but also 74% of the two hundred fifty students questioned ranked their teamwork learning at four or higher on a five-

point Likert scale (Martinez, Gonzalez, Campoy, Garcia-Sanchez, & Ortega-Mier, 2014). At the University of Sydney, a teamwork skills program for midwifery students has been developed which goes beyond these examples and demonstrates teaching to level three of Earnest et al. (2017) framework. In the School of Medicine's TeamUP model, there are various teamwork interventions throughout the midwifery course program, with an overarching rubric measuring five teamwork domains, which are both instructor and peer assessed. Throughout the three-year program, the students are provided with teamwork specific lectures and assignments centered on their practice. Hastie (2018) found that this model supported students to develop and practice their teamwork skills and develop the social, emotional, and practical behaviors to become competent team members.

There are, unfortunately, very few multidisciplinary teamwork experiences reported in the engineering educational literature; however, two universities in Chile have their informatics, and naval engineering students collaborate on a six-week long intensive design challenge to help them develop their multidisciplinary teamwork skills (Maturana, Tampier, Serandour, & Luco, 2014). Their study of the one hundred students involved in the design challenge found through a peer evaluation and a metacognition survey that the peer evaluation tool was very useful to the students as a feedback loop, to help them understand their strengths and weaknesses and to allow them to focus on and improve the skills their peers had identified. The Engineering Projects in Community Service (EPICS) program at Purdue University is also a multidisciplinary academic service learning program integrated into the engineering curriculum; with over three hundred students completing a reflection questionnaire on their experience in the program, the students picked teamwork as their most important learning from the program. EPICS project teams are supported by mentors, who are drawn from engineering and non-engineering faculty, and

industry professionals and their coaching is seen as fundamental to the success of the program in developing professional and global competency (Zoltowski & Oakes, 2014).

Project management.

Based on a study of engineering and management students at four universities in the U.K., there are five explicit and implicit dimensions of project management learning that engineering students see during their studies: transferrable skills, analytic skills, in-class collaboration, out-of-class collaboration, and curriculum balancing (Ojiako, Chipulu, Ashleigh, & Williams, 2014). Interestingly, there were differences between the engineering and management students, with the engineering students not seeing the comparative value of analytical skills to project management but placing much higher value in transferable skills than the management students. This may be due to the engineering students seeing project management as a portion of their skill set, rather than the primary focus, as the management students would. There are several methods of implementing project management as part of the engineering curriculum. In five engineering departments across several universities in Spain, a virtual project management platform was developed so that engineering students taking project management courses at their respective universities could then work together through a shared virtual experience to execute and manage their projects (Alba-Elias, Gonzalez-Marcos, & Ordieres-Mere, 2014). This integrated solution is very beneficial to student learning but does require a high level of input from the instructors. In Spain, a study focused on project management for computing science students compared students in either a course developed with a student-centered approach or a more traditional, control course. The research found that the student-centered, contextualized, project-based learning with virtual teamwork was more effective than traditional teaching approaches (Gonzales, Potts, Hart-Davidson, & McLeod,

2016) and led the authors to create a competency assessment method based on student participation and value creation (González-Marcos, Alba-Elías, & Ordieres-Meré, 2016). Other programs (Barka, Benhayoune, El Ouafi, Brousseau, & Menou, 2014) have found that integrating project management into design courses increases students' overall professional and design skills levels by encouraging students to understand the entire design process, rather than see it as a technical exercise. As an additional layer to creating a more realistic project scenario, it has been found that setting up project teams to include different roles, such as project manager, increases students' overall class grades, particularly if they are supported and mentored by, and can model themselves on expert project managers (Gonzalez-Marcos, Alba-Elias, Ordieres-Mere, Alfonso-Cendon, & Castejon-Limas, 2016; Warin, Talbi, Kolski, & Hoogstoel, 2016), and also enables students to gain valuable professional skills compared with traditional design classes by helping students understand the role of engineering professional skills (Gilbuena, Sherrett, Gummer, Champagne, & Koretsky, 2015).

Innovation and entrepreneurship.

Teaching innovation and in particular entrepreneurship in engineering colleges is complicated. When thirty-seven instructors who teach entrepreneurship to engineering students were asked about their teaching entrepreneurship, they responded that the “entrepreneurial mindset” is based on personality characteristics, not skills, and 77% of the instructors believe that while this mindset can be developed, it is based on the individual's innate personality and not every student is suitable (Zappe, Hochstedt, Kisenwether, & Shartrand, 2013). While the United States, based on a comparison of student reflections, does teach significantly more of the process of innovation, engineering students see a significant link between entrepreneurship, innovation, and creativity and less than a third of engineering students feel that they gain

education in creativity in their engineering courses (Edwards-Schachter, García-Granero, Sánchez-Barrioluengo, Quesada-Pineda, & Amara, 2015). Across all undergraduate courses including engineering, there is a growing acknowledgement that entrepreneurship teaching in the United States has to become more reflective and grounded in real-world contexts (Hemant, Jeff, Eric, & Doan, 2015), findings that were generally also reflected in a study of students in Germany, who found their entrepreneurship education to be technically focused but not grounded in the real world (Oehler, Höfer, & Schalkowski, 2015).

C. Jones, Matlay, Penaluna, and Penaluna (2014) established three types of entrepreneurship education: education about entrepreneurship, education for entrepreneurship, and education through entrepreneurship. While education through entrepreneurship is seen as being the most student-centered, the entrepreneurship process within the class is still generally taught as a process; the course leads the student through the stages from idea to market offering, rather than through application, in that the students have a goal in mind and have to reach that goal with the resources available to them, which is much more self-directed and explorative than being simply taught the process, but is also more challenging for the instructor and students (Franziska & Sarah, 2017; Krakauer, Serra, & Almeida, 2017). A study at Pennsylvania State University found that within engineering, entrepreneurship teaching is even more limited. The study determined that the process of creativity taught in engineering design is limited to idea generation, and that the continuation of the process, through concept iteration and selection to the final design or product, is often not a part of the curriculum, which leads students to abandon their ideas for more conventional solutions (Starkey, Toh, & Miller, 2016). At the University of Pretoria, this has led to the creation of a design-build-innovate course in which the students go from ideation through developing business plans and exploring the patent potential for their

ideas. The students are supported by teaching assistants who are trained by the Department of Psychology in mentorship, to help them accelerate the student's ideation and design processes. The engineering students have demonstrated a significant increase in interest and understanding of innovation and engineering over the previous traditional design course as well as an increased understanding of the link between engineering theory and practice (Liebenberg & Mathews, 2012). Both this study and a similar study at the Tallinn University of Technology found that this connection between theory and practice was significantly increased through course designs that cover the full design process; the study at the Tallinn University of Technology also found a significant increase in the metacognitive (or higher-order, thinking about the process of thinking) abilities of students that undertake courses designed in this way (Ling & Venesaar, 2015).

Global preparedness theme.

Similar to engineering professional competencies, global preparedness is an area of engineering education which is being seen as increasingly important by the engineering profession (Streiner, Vila-Parrish, & Warnick, 2015), and civil society but is lacking in most engineering degree programs globally (United Nations Educational Scientific and Cultural Organization, 2010, pp. 308-309). Indeed, a study conducted at four top engineering colleges in the North East of the U.S. found that while students enter engineering degree programs with a sense of engineering's role in civil society, sustainability and both domestic and global development (Dunsmore, Turns, & Yellin, 2011), the culture of disengagement they experience throughout their degree program socializes them to disassociate engineering from context (Cech, 2014). This culture may be a factor in the number of students who choose to leave engineering programs, particularly female students who studies show, are generally more interested in studying engineering due to its impact on the environment, people and society (Diekmann, Brown,

Johnston, & Clark, 2010; Diekman, Clark, Johnston, Brown, & Steinberg, 2011; Saavedra, Araújo, Taveira, & Vieira, 2014). Utilizing global preparedness, to re-center engineering degree programs in the context and realities of practicing engineering has been found to be an effective method of retaining more female engineering students (Eschenbach, Cashman, Waller, & Lord, 2005), keeping all students engaged in engineering (Dancz, Bilec, & Landis, 2018; Henein, 2017) and supports students development of engineering competencies and experiences engineering industry is finding increasingly important (Neumeyer, Chen, & McKenna, 2013). In this study, engineering students' efficacy in global preparedness is seen as closely related to ABET criteria 3h (Hariharan & Ayyagari, 2016)—“the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context” (Accreditation Board for Engineering and Technology, 2016)—although it also has connections across all of the ABET student outcomes, such as ethics, communication, and knowledge of contemporary issues. Global preparedness has been recognized and promoted by both the professional and educational engineering communities at conferences and in national reports and publications as fundamental to the future of engineering (American Society for Engineering Education, 2010). The sub-constructs within this section are drawn from a synthesis of the attributes of a globally competent engineer as expanded on in Table 6 (Allert et al., 2007).

Diverse or multicultural environments.

Given the global mobility of the engineering workforce, and the diverse and multicultural environments engineers can find themselves working in, engineering students should be comfortable working in and understanding such environments and their complexities (Jesiek, Shen, & Haller, 2012; Streiner et al., 2015; Yu, 2012). While international travel can help students develop these skills, they can also be taught through domestic programs (Lattuca,

Knight, Ro, & Novoselich, 2017). A third of engineering students taking part in the EPICS (Engineering Projects In Community Service) program at Purdue University during the 2013-14 academic year stated that learning to work on multidisciplinary and diverse teams was one of the most valuable things they learned from the course (Zoltowski & Oakes, 2014). Alternatively, a study of engineering students across seven countries who worked together on diverse, multicultural virtual design teams found a correlation between high levels of diversity and high levels of creativity, rationalizing that the multitude of different views and cultures within a team increased the overall creativity. However, the study also found that the levels of trust and cohesion in the team were lessened by higher levels of diversity, an issue multiplied by the virtual nature of the teams (Cok, Fain, Vukasinovic, & Zavbi, 2015; Y. Li et al., 2017). Students in international collaborations do recognize the heightened importance of trust in virtual teams and that communication is fundamental to building trust (Esparragoza et al., 2015).

The Pontificia Universidad Católica de Chile has developed a course to help enable computer science students to actively contribute within multicultural and transdisciplinary teams; nearly 80% of students reported the course had helped them to understand interdisciplinary and multicultural issues (Verdugo et al., 2013). This semester-long course leads the students through a cultural framework, which supports the students' understanding of the constructs that create a culture and how to understand the application of these frameworks to the problems they will face as computing scientists through a lecture and discussion-based format. A review of studies into study abroad opportunities, supplemented by surveys of students who had studied abroad, found that bringing students into contact with diverse populations increases both their inter-cultural and multicultural skills (Engberg, 2013). This idea is also supported by research conducted at Purdue University (Jesiek et al., 2012), where all students returning from an international research

experience in China agreed or strongly agreed with the statement, “I will be able to work more effectively in a diverse and multicultural environment” (Lail et al. (2013). This suggests that curriculum focused on preparing students for working in diverse or multicultural environments has strong links to developing engineering students’ ethical practice, given the understanding of complex socio-economic, cultural, political, and legal contexts and the ethical issues to which work in such environments may require one to attend.

The need for multicultural or diversity preparation is a particular focus for students in psychology and teacher training programs at U.S. universities. Milton and Casey (2016) studied two hundred undergraduate psychology programs across the United States and found that while most offered diversity or multicultural courses, at most universities these are optional, non-core classes and they typically covered multiculturalism or diversity very simplistically, giving little or no coverage to intersectionality. In education, due to the activist roles that pre-college teachers are finding themselves in (Riley & Solic, 2017), there is an increasing recognition to train teachers deeply in the complexities of diversity and multicultural classrooms and contexts, along with individual intersectionality and how it affects students (J. R. Jones, 2015). To help pre-service teachers begin to develop this understanding, the University of Canberra in Australia has placed them in linguistically and culturally different professional settings through international service placements. The teachers that have undertaken this experience have reported changed thinking about their own biases, perspectives, and professional practices and it has, overall, been a positive influence on them personally and professionally (Walkington, 2015).

Language skills.

Foreign language skill is a significant challenge in global teams (Mohtar & Dare, 2012) and a socio-cultural barrier for engineers working outside their native culture (Hoda, Babar,

Shastri, & Yaqoob, 2017). This skill is widely recognized by business as essential, despite the falling number of applications to foreign language departments, as students look for programs with higher perceived value for their future careers (Mills & Moulton, 2017). As part of a study of global competencies considered during the hiring process by multinational engineering companies, proficiency in a second language was the highest mentioned global competency (Streiner et al., 2015). There may be a gap between reality and student expectations, however, as a study of chemical engineering students at the University of Strathclyde, Scotland, found that the lowest ranked employability skill was ability in a foreign language, despite students recognizing the importance of language skills to careers in industry and research (Fletcher et al., 2017). A study undertaken at Clemson University comparing engineering students choosing an international senior capstone design course and those taking a traditional domestic senior capstone design course found that students recognized the importance of foreign languages and that learning or improving non-English language skills was a motivator for those choosing the international option (Morkos, Summers, & Thoe, 2014). However, at the end of their international experience the students reported disappointment with the program, as it did not formally support foreign language learning and students, therefore, had not gained language skills as they had hoped. Similar findings were also disclosed by engineering students who have been part of the Global Design Team service-learning program at Purdue University, where proficiency in a second language seemed to be the outcome least addressed by the students' experiences in Kenya or Palestine (Mohtar & Dare, 2012).

Similarly, foreign language study is also seen by students as an essential part of study abroad experiences, a fact that is often not recognized by the partners providing the study abroad opportunity. American engineering student participants in a ten-week international research

experience in the Czech Republic commented on their disappointment in a lack of formal language training as part of the experience, with less than half of the students reporting any change in their foreign language proficiency (Bender, Yaffee, & Lopatto, 2017).

This uncovers a substantial challenge with foreign language instruction for vocationally focused students, such as engineers, in that the instruction when available in a foreign language is not appropriate to the students' goals for learning the foreign language. Han (2015) found through interviews with one hundred forty-seven first-year engineering students in Turkey who were trying to learn English as a second language that students' response to a lack of foreign language learning support in universities is that they align their language learning strategy with the real-life application they believe to be appropriate, so they learn through watching and reading in the language they want to learn and see vocabulary as much more practical and essential than grammar. A study at the Kazan Federal University in Russia reinforced this finding, demonstrating that the success of foreign language teaching is based on understanding students' motivations for learning a foreign language and grounding the teaching in the context of their interests (Fahrutdinov, Fahrutdinova, & Absatova, 2017). It is important, however, that at this university foreign language is seen as a critical part of students gaining cultural competence (Nurmieva & Kiyashchenko, 2017). Maxim (2014) expands on the structure of learning within most foreign language departments that exasperates this issue. In most language programs there is a division between lower-level and higher-level foreign language classes; lower-level classes teach the structure/grammar necessary to read, write, and speak in a language, while upper-level classes teach the vocabulary of the language. Most engineering students only take lower-level classes and so do not reach the content classes, which would fulfill the foreign language goals they find most important. This issue is being deepened by the

decrease in the number of students applying to major in foreign languages. Research showing that those who do apply are more interested in the language itself, rather than the content (Mills & Moulton, 2017) to which engineering students who are minoring in foreign languages are drawn.

Global/international/trans-national experience.

Traditionally, engineering students gain global experience through studying or interning abroad, cocurricular programs (Litchfield, Javernick-Will, & Maul, 2016), and increasingly, through capstone design classes or research fellowships (Wheatley et al., 2017) conducted partially or completely in a different country (Dai et al., 2016). There are, however, an increasing number of engineering courses in which students and instructors may be from a single geographic location that either incorporate global context into the course or utilize improvements in technology to create global courses through interactive learning environments.

The Universidad Politécnica de Valencia (UPdV) partnered with the NGO Ingenieros Sin Fronteras (Engineers Without Borders Spain) to develop elective engineering courses that integrated global development engineering, centered in Nussbaum's conceptualization of cosmopolitan citizenship and based around the following four constructs (Bader, 1999) to address the drift of engineering education toward an entirely technical subject:

- The ability to learn more about ourselves;
- The need to solve global problems through international cooperation;
- The acknowledgment of moral obligations to the rest of the world;
- To be able to prepare a robust and coherent series of arguments based on the differences that we are prepared to defend. (Boni, MacDonald, & Peris, 2012)

The incorporation of what may be thought of as the humanities back into engineering is central to bringing the global context into on-campus courses, and the students who have taken the global development engineering course at UPdV have reported an increase in their levels of global awareness and citizenship. Gilbert (2014) studied an interdisciplinary program involving the collaboration of social work and engineering students as part of a three-course Projects in Underserved Communities (PUC) program that includes some field work; she found that the students' gains in global understanding, mainly achieved through peer learning, are a primary success of the program.

Alternatively, global courses rely heavily on collaborative and interactive virtual learning environments (Daniels, Cajander, Clear, & McDermott, 2015) or the use of communication and collaboration platforms such as Skype, Blackboard, and WhatsApp among others (Davison et al., 2017). These courses, however, tend toward mixed results regarding student satisfaction, with many frustrated by technological issues or cultural communication issues for which they may not have been prepared (Dai et al., 2016). At the Technische Universitat München, global courses have been taken a step further through the redesign of the traditional capstone software design course to incorporate a virtual environment through which students communicate and collaborate with their industrial sponsors (Bruegge, Krusche, & Alperowitz, 2015); this serves as preparation for careers in software engineering, where virtual and international collaborations are becoming the norm. RMIT University in Australia has developed a novel trans-national core undergraduate art history and theory class that is offered in three different countries: Australia, Hong Kong, and Vietnam. Students in all three locations criticized this class, which was focused on European and North American art, and to address this, the instructors wanted to bring in reflections relevant to their local context and to allow the students to translate their learning into

their practice as artists. The revised course is student-centered and -driven, involving much more self-directed research, self-reflexivity, and peer feedback, which allow students to situate the history and theory in the context that interests them. These changes have dramatically improved the quality of the class and the student feedback received (Clarke, Sharp, & Tai, 2017).

Finally, it is interesting to note that of all the studies included in this review, only one partially recognizes the critique of terminology such as *global* or *international*, as described by the Swedish anthropologist Hannerz (2002, p. 6):

I am also somewhat uncomfortable with the rather prodigious use of the term globalization to describe just about any process or relationship that somehow crosses state boundaries [...] The term ‘transnational’ is in a way more humble [...] it also makes the point that many of the linkages in question are not ‘international’ in the strict sense of involving nation [...] In the transnational arena, the actors may now be individuals, groups, governments, business enterprises, and in no small part it is this diversity of organization we need to consider. (p. 6)

Streiner et al. (2015), in exploring the global competencies considered by multinational companies, described the context in which professional skills are applied by globally competent engineers as *transnational*, rather than the more traditional terms *global* or *international*, thus demonstrating an understanding of the positivist nature of these terms (Schiller, 2005). However, this conceptualization is not widely utilized in engineering educational literature.

Global citizenship.

Global citizenship is a term that is widely used in education across the world but has several different definitions and conceptualizations based on the socio-economic context in which it is utilized (Oxley & Morris, 2013). However, the term is also criticized as being a

conceptual oxymoron, as citizenship by definition is based on a relationship with a political or geographic community (Bowden, 2003). Global citizenship is, as such, seen as a western, elitist conceptualization because only those with privilege can see themselves as citizens of more than their community (Jooste & Heleta, 2017). Many authors, however, see *global citizenship* as a “descriptive term, intended to capture various cross-border identities, relationships and allegiances that have been developing during the current period of intensive globalization” (Bosniak, 2000). Based on a five-year cross-university curriculum internationalization project in the United Kingdom, Killick (2013) argued that to become a global citizen, a student must move their perspective from “act-in-the-world” and “what-I-can” to “self-in-the-world” and “who-I-am” as further outlined in *Figure 10*. This construction of the underlying understanding of “being” a global citizen and the self-realization necessary indicated the difficulty of teaching global citizenship, particularly doing so on campus without international travel.

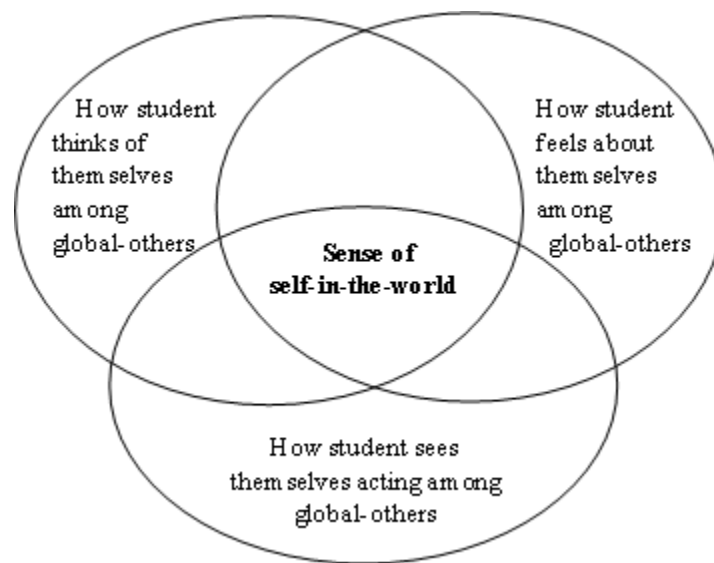


Figure 10. Representation of the constructs within self-in-the-world. Reprinted from *Global citizenship, sojourning students and campus communities*, D. Killick, 2013, *Teaching in Higher Education*, 18(7). Copyright 2013 by Taylor & Francis

As a solution to this identified issue, Georgia State University has within its arts program classes that are based on Augusto Boal (1985) theatrical theatre pedagogy, which was inspired

by Paulo Freire's work, "Pedagogy of the Oppressed" (1970). Over the past two years, Georgia State's art program has conceptualized how to use Freire's work to support art students' formation as global citizens; the critical pathways and social justice espoused by Freire have enabled them to create the context and environment to teach global citizenship on campus, supporting students to understand social injustice in the local community (Kang, Mehranian, & Hyatt, 2017). In Japan and Canada, two universities' teacher training programs are also utilizing this social justice approach to empower student teachers with the knowledge and sense of self-in-the-world to be able to create global citizenship education for pre-college levels (Howe, 2013).

These studies are part of the emerging, publicly available body of literature developed around the teaching and enculturation of global citizenship into education (Oxley & Morris, 2013). However, very little literature focused on global citizenship and engineering education is available. In Europe, despite the impact on students global citizenship of well-established programs such as the European Union ERASMUS exchange (Karatekin & Taban, 2018) and the wider impact of the Bologna Accord (Zmas, 2015) on education in Europe, Blum and Bourn (2013) noted that in the United Kingdom, while there is growing interest from engineering students in developing their global citizenship, engineering education lags behind other educational fields in developing curriculum and support for this area.

Cultural and global awareness.

Utilizing a series of small-scale literature reviews that were validated through interviews with engineering managers working in industry, Fisher et al. (2017) found that the main avenues for students to gain global awareness are through academic competitions, campus and cultural communities, housing communities, project teams, service organizations, and student governance opportunities. Clemson University conducted a study comparing the difference in

change of global awareness in undergraduate engineering students who had undertaken an international study abroad capstone design course compared with students who had taken a traditional on-campus capstone design course (Morkos et al., 2014). Faculty support these courses, and their own professional development by travelling to, and working with the partners in other countries, to develop the relationships and design projects needed for the course. The students' pre-course reasons for taking both courses were reasonably similar, although students taking the international option were slightly more interested in learning about the United States and world affairs/history. The study found that there was no statistically significant change between the pre- and post-test survey responses related to the global awareness of the students who took either the domestic or the international course. However, interviews with the students uncovered that those who studied internationally had experienced a change in cultural awareness and had struggled with the complexities of working with an international team and language and cultural differences and thus had become more aware of their own individual strengths and weaknesses. This finding was echoed by a study on engineering student experiences in an international service learning program in Ireland (Daniel & Mishra, 2017); students who choose to study internationally had a higher level of global awareness before the program and this awareness did not significantly change after the program, but all of the students related through interviews an increased depth of cultural awareness. Nursing accreditation bodies, similar to the ABET accreditation in engineering (Accreditation Board for Engineering and Technology, 2016), have added global healthcare as an area of core knowledge for nursing students. In response to this, the University of South Florida developed an international clinical experience for undergraduate students to develop their cultural awareness and global healthcare knowledge; the researchers found that while the experience was challenging to set up and support, it was

very important to students' development as future global healthcare leaders (Visovsky, McGhee, Jordan, Dominic, & Morrison-Beedy, 2016).

Socio-cultural understanding.

Two studies demonstrated the apparent relevance of socio-cultural understanding to innovation and entrepreneurship; the first focused on engineering students at three universities in Estonia (Täks, Tynjälä, Toding, Kukemelk, & Venesaar, 2014), and the second study compared engineering students in North America and Spain (Edwards-Schachter et al., 2015). For these authors it seems evident that innovation or the process of creativity requires socio-cultural knowledge as part of the problem-solving process. Hoda et al. (2017) interviewed fourteen academics who teach five different global software engineering courses at ten universities across eight countries (Australia, Canada, Italy, Denmark, Switzerland, Germany, Sweden, and Croatia) to uncover socio-cultural challenges in teaching globally distributed courses; They determined that the main socio-cultural issues that students experience are language differences, the concept of time, attitude toward grades, national culture assumptions, differences in autonomy, and the differing influence of the lecturers.

In agricultural education, the University of Missouri is utilizing the concept of wicked problems, a concept brought to engineering education by Engineers for a Sustainable World, (Dale et al., 2014; Hess, Aileen, & Dale, 2014) to help students understand and manage socio-cultural issues found within agriculture and agro-economics through a series of vignettes based on different complex ecological, economic, and social challenges (Murakami, Hendrickson, & Siegel, 2017). Students found this approach very useful in their decision to pursue—or not—a career in sustainable agriculture. Similarly, Appalachian State University has utilized problem-based learning and civic engagement as methodologies within the undergraduate degree in

communication sciences and disorders to improve the socio-cultural perceptions of the students, enabling them to be more empathetic with their patients and clients (Keegan, Losardo, & McCullough, 2017).

Discussion

While there are differing frameworks for the connection between professional skills and global preparedness (Allert et al., 2007; Jesiek, Zhu, Woo, Thompson, & Mazzurco, 2014; Ragusa, 2014), it is clear that the constructs within global preparedness are built upon the professional skills needed to be a competent engineer and that there is an increasing focus across the world on teaching engineering students professional skills and global competency. It is also apparent that, despite the fears of many educators, it is possible to include professional skills and global competency in the curriculum through the redesign or alteration of the context and culture of existing courses without adding additional credit requirements to engineering programs and according to stakeholders in engineering education across the world, key to the future of engineering education. Many of the examples also demonstrate that stand-alone classes in professional skills have some impact. However, students appear to prefer and become competent more quickly if the skills are embedded into their engineering classes (Monteiro, 2017; Passow & Passow, 2017). Most of the programs included in this review showed that the preferred method to infuse professional skills and global competency into the curriculum is through engineering design projects or other “real life” active, problem-based classes and programs. This is a positive direction that students are indicating they prefer, as it should lead engineering education to de-silo technical, professional and global competencies. Students prefer to be taught in a more holistic way, with their classes including all the dimensions and competencies needed to be an engineer, which would lead to engineering education being more reflective of

the realities of engineering practice. In many ways, the recent explosion in international development is a demonstration of engineering education beginning to respond to this direction from engineering students as these programs create scenarios that require students to develop more than simple technical solutions, by encouraging the students to understand how their design fits into the overall context and culture.

While there is a significant focus on educating engineers in professional skills, the emerging requirement for engineers to also be globally prepared is relatively new to engineering education, and there are fewer validated studies available for review. It is, however, promising to see that engineering education instructors and researchers interested in this area appear to be collaborating across disciplines and majors both within their own campus and with collaborating universities to create exciting, dynamic, and challenging courses for their students, as part of the important drive toward educating engineers fit for our global future (Besterfield-Sacre, Cox, Borrego, Beddoes, & Zhu, 2014; Elhouar & Al-Khafaji, 2014; Fisher, 2014; King, 2008; Rajala, 2012). This is demonstrated through the growth of international development focused engineering programs across the United States, as engineering education reacts to the requirement from industry to prepare students for the complex realities of global engineering practice, incorporating technical, professional and global competencies. The changing demographics of the engineering student body may also be driving this change, as increased diversity is increasing student's interest in learning about, and working with, different cultures and communities both in the United States and across the world.

Conclusion and Research Recommendations

This systematic literature review developed an understanding of the two least understood dimensions of engineering global preparedness, the associated professional skills and global

competencies (Allert et al., 2007) and was designed as a contribution to the small but growing field of systematic reviews in engineering education. As summarized by Borrego et al. (2014), systematic reviews are common practice in well-established fields such as education, psychology, and engineering; however, in the period from 1990-2014, only fourteen such reviews were identified in engineering education. Passow and Passow (2017) recently published a systematic review concentrated on the competencies that undergraduate engineering programs should emphasize based on an analysis of engineering job listings, and this review aims to build on their work by synthesizing the competencies their review explored with other relevant but older studies (Allert et al., 2007; American Society for Engineering Education, 2013; Bourn & Neal, 2008; King, 2008) and explores how these competencies are currently being taught.

This study also deepens focus on the importance of the competencies stakeholders in engineering practice and education state are needed for the future of engineering, by developing an understanding of global preparedness for engineers based on previous studies undertaken in this area (Allert et al., 2007; American Society for Engineering Education, 2010; Bourn & Neal, 2008; Gregg, 2011; Hariharan & Ayyagari, 2016; Huntley, 2014; King, 2008; Parkinson, 2009). This study found that there is broad agreement in the areas of professional competency engineering students should be developing and that they are generally defined by skills; ethics, leadership, communication, multidisciplinary teamwork, project management, innovation and entrepreneurship and that both in the U.S. and globally, there are many examples of how engineering educators are supporting student's development of these competencies through integration into their engineering classes, or through separate interventions. Global competency is an area with less clarity and consensus, with the competencies found to be defined by attitudes, rather than skills. Students should be required to develop their ability to work in diverse or

multicultural environments, to become global citizens, develop cultural and global awareness and socio-cultural understanding through gaining global, international or trans-national experience (of which, gaining language skills may be a crucial component). Through highlighting the importance of professional and global competencies to engineering student's future careers, and successful practices for teaching to these competencies, engineering educators can utilize this study to identify opportunities and ideate methods of increasing engineering students professional and global competency.

This study also asks the question of the future of engineering competency, by asking if the different areas of competency (professional and global) identified in this study should be seen as separate, or if they should be recognized and taught as a part of the systematic, holistic reality of engineering, in line with real-life engineering practice. It is hoped that engineering competency development, and the engineering classes and programs identified in this study demonstrate a future where competency isn't siloed and is instead, taught through methods that mirror actual engineering practice. This study has identified methods that instructors can use to bring the depth and complexity of engineering practice into the classroom, such as situating engineering design projects in unfamiliar cultures or contexts, designing classes so that communication, financial management, working with external or internal stakeholders, project management and leadership is an important factor in the success of engineering design projects. Through integrating these engineering realities into engineering classes, students can have the opportunity to learn, test, practice and reflect on the non-technical competencies on which engineering practice relies.

An issue that is somewhat hidden in the cases outlined in this study is the ability and comfort level of engineering instructors to teach professional competencies and global

preparedness. There is an inherent issue that most engineering educators do not have any teaching training or licensure (Abel, 2018), and are not required to do so. Therefore, without additional support and training faculty and instructors may not be competent or comfortable teaching to the non-technical aspects of engineering or invoking global contexts in their teaching if they don't have personal experience in these areas. Most, if not all of the teaching cases within this study are led by instructors who are drawing on their own personal experiences, through their work or lived experience, or other education or training they have undertaken to create courses or learning opportunities that they are comfortable, due to their individual experience, teaching. There are options that faculty and instructors who are looking to embed non-technical competencies into their courses can take advantage of. Some programs, such as the EWB Challenge provide optional workshop training for instructors teaching the program at institutions, to prepare them with knowledge of engineering for international development and of the global context in which the program is placed (Cutler, Borrego, & Loden, 2010; Mattiussi, 2013). This is a significant factor in the number of university NGO partnership programs found in this study, which bring together experiences and expertise that complement each other to create innovative and effective programs to support students professional and global competency development. Faculty at the Universidad Austral de Chile have been supported through training and funding from the Chilean Government and the World Bank in active learning methods and identifying and teaching competencies that align with the universities commitments to sustainable development, respect for diversity and social responsibility in engineering (Maturana et al., 2014). Faculty exchanges are also recognized as a method of faculty gaining global competence, although these experiences may have similar issues to students' study abroad, in that without the correct support and structure, faculty may not gain any significant global competence through

travelling abroad. Alternative methods of structured faculty training such as overseas professional development, and international professional training do alleviate some of these issues (Morkos et al., 2014).

Other programs partner with industry (Gerolamo & Gambi, 2013) or departments/instructors outside of engineering but within the institution that have the experience and expertise to deliver professional competency and global preparedness (Babuscia et al., 2012; Sivapalan, 2017). If these programs are co-taught and fully integrated between the engineering educator and the external expert, the issue of students not understanding the relevance of teaching that is not integrated with engineering highlighted by Cadieux et al. (2017) could be overcome.

Therefore, it is suggested that future research could build on these reviews of the professional skills and global preparedness engineering students need, and the examples of educational methods used to teach them, to develop engineering courses and programs that are relevant to the future of engineering and how to empower engineering educators to teach professional skills and global preparedness on campus. An initial study in this area found that internationalization interventions on campus at the University of Minnesota led to over twelve thousand students from all programs and colleges reporting more one-on-one interaction with international students and students of other cultures than those who studied abroad, and that their perceived “return on investment” was higher (Soria & Troisi, 2013). This aligns with a fundamental theme that emerged through this article, the importance of real-life situations and context to the learning of both professional skills and global preparedness. Given the cost to students of real-life international experiences, “real-life” scenarios or simulations that are open and available to all students on campus should be of particular interest to instructors,

administrators and other stakeholders who are engaged in increasing opportunities for all students to gain global preparedness, although further research is needed to compare the gains and “return on investment” of these attempts to internationalize programs and curricula compared to those programs and classes that situate students in the global context. A further area of study could be comparing different models of support to instructors that enable them to teach areas of competency in which they may not have the experience or expertise from their own lived experience, as from the literature found in this study, this may be a significant hurdle to providing support to students.

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Article 2: Understanding First-Year Engineering Undergraduate Students' Global Preparedness through the EWB Challenge International Development Design Class

Introduction

The United Nations Sustainable Development Goals (United Nations, 2016) require engineers who are defined by their holistic understanding in that they not only need to be technically competent but are also required to have the global and professional skills to be able to practice engineering both inside and outside their native context and culture (Wong, 2016). The barrier created by engineering education is that graduating engineering students are often not prepared with the competencies needed to work in a global workplace. Competency in ethics, communication, and cultural and global adaptability are needed to prepare engineering graduates to work on transnational teams in different socioeconomic and regulatory contexts (Bourn & Neal, 2008). The United Nations Educational, Scientific, and Cultural Organization's (UNESCO) report "Engineering: Issues, Challenges, and Opportunities for Development" (United Nations Educational Scientific and Cultural Organization, 2010) suggest the model in Figure 11, which re-centers engineering in a systematic model that moves away from engineering design as a scientific/technologically focused vocation. The proposed model reconnects engineering to its role in providing products and benefits that fulfill the needs of society and nature using technology and scientific theories.

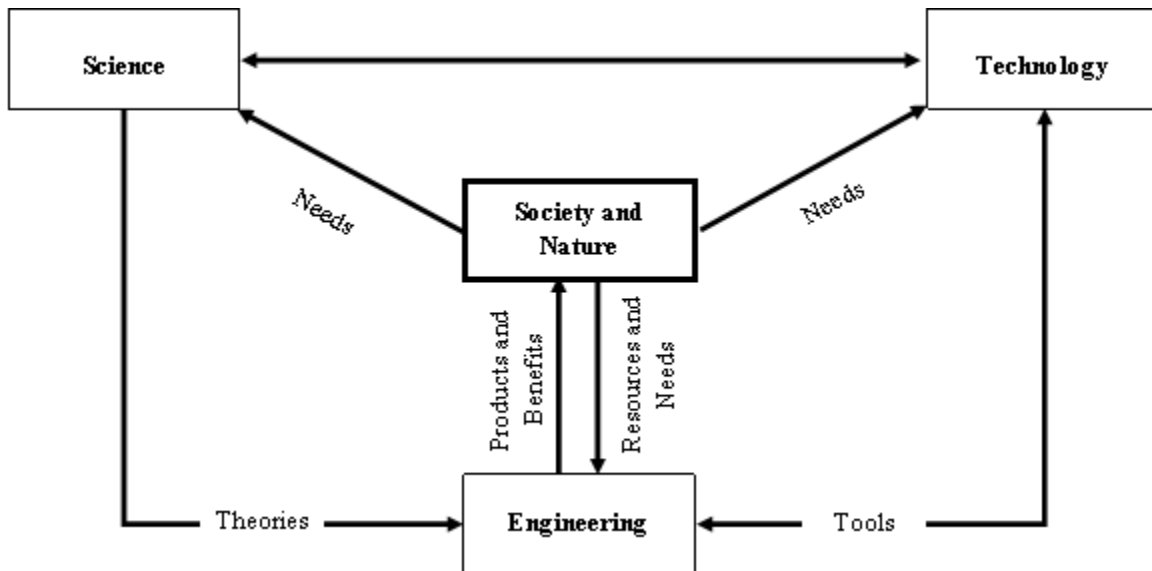


Figure 11. Engineering System Model. Adapted from *Engineering: Issues, challenges and opportunities for development* (p.25), UNESCO, 2010, Paris, France. UNESCO Publishing. Copyright 2010 by UNESCO Publishing

This model suggests the need for engineering classes that teach students how to understand and respond to the global needs of society and nature using engineering theories and tools. Engineers who are taught to develop this utopian thinking (Ravesteijn & DeGraaff, 2003) provide the capacity for the development of what UNESCO defines as “engineering for development.” This approach is also modelled by Engineering for Change in the United States, a new interdisciplinary worldwide thrust that:

Responds to the global need for engineers who understand the problems of development and sustainability, can bring to bear on them their engineering knowledge, are motivated by a sense of the future, and are able to interact with other disciplines, with communities and with political leaders to design and implement solutions. (United Nations Educational Scientific and Cultural Organization, 2010)

Research Question

There are several programs and courses in the U.S. and globally that are responding to the call from the United Nations and UNESCO to provide students with the opportunity to build

global preparedness. This article provides a brief overview of recognized curricular and cocurricular programs and courses available to students at United States institutions before investigating the impact of one of these programs on students at a mid-sized, western U.S. university by answering the following research question:

- What, if any, differences are there between a globally oriented project (EWB) and a traditional introductory course on the development of global preparedness and professional skills over a one-semester first-year civil and environmental engineering course?

Programs preparing Engineering Students to work in Engineering for Global Development

In response to global need and students' educational desires, there are a growing number of curricular and cocurricular classes and programs for engineering students to engage with engineering for development (Smith et al., 2017; Trimingham et al., 2016). In general, these programs tend to be partnerships between universities and non-government organizations (NGO) that work in communities globally, and that may be experiencing issues that engineering expertise could help solve or manage. Some of these programs are credit-bearing, having been designed as part of either on-campus or study abroad/internship curricular opportunities. Other approaches may be closer to volunteer opportunities that exist through student chapters of NGOs or student support organizations on campus. In general, all are variations on experiential learning models where students are involved in a real or simulated situation and help students to develop experience based on "real" situations and learn how to abstract concepts and generalizations through reflective observation and active experimentation (Dewey, 1939; Kolb, 1984). This methodology is seen as highly appropriate to engineering education, due to the applied nature of the students' studies and career goals, along with the fact that engineering is an

interactive field that requires working in teams with other stakeholders (Dancz, Bilec, & Landis, 2018; Hajshirmohammadi, 2017).

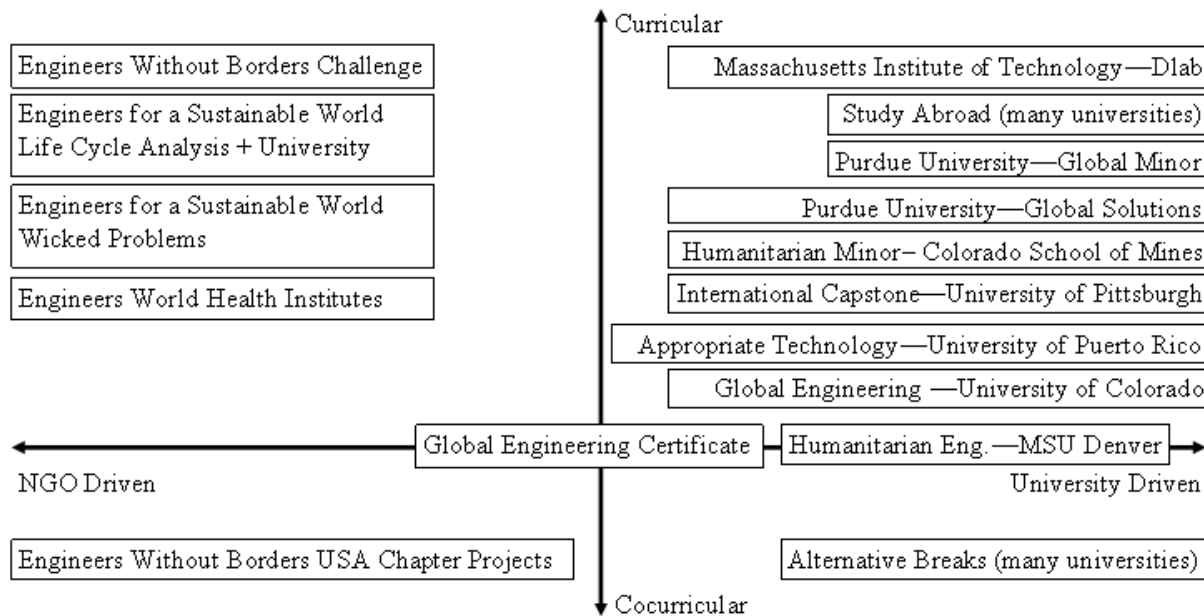


Figure 12. Example cases of engineering classes and programs organized by driving organization and curricular involvement

While all the programs and courses in Figure 12 are experiential in nature, there are different drivers for each of the programs, either the programs are driven by the institution, or by an external party, often an NGO. Figure 12 demonstrates that most of the programs available to students in the United States are curricular in nature, with the two notable exceptions. Engineers Without Borders USA (EWB-USA) chapter projects and alternative breaks, which are short term community service projects often organized, or marketed by the students institution (Niehaus, 2017). Increasingly however, even EWB-USA projects and alternative breaks are being marketed for and assessed on their learning impact on students, often their impact on students' professional competency and global preparedness (Litchfield & Javernick-Will, 2014; Litchfield, Javernick-Will, & Maul, 2016; Mann & DeAngelo, 2016). This change, even in cocurricular programs, demonstrates why most programs found in the engineering for global development

space are curricular. Students, institutions and faculty value programs that are a part of, rather than an addition to, their already busy schedules, despite the demonstrated value of cocurricular programs to engineering students academic achievement (Wilson et al., 2014), particularly for underrepresented minority groups (Gonzalez & Millunchick, 2016). It can be argued that faculty and institutions are recognizing the culture of disengagement in engineering education (Cech, 2014) and so are increasing the experiential and service related content of courses and programs. Faculty appear to prefer to increase this within the curriculum rather than through additional, external projects and programs that do not build directly towards student's degree programs, given the time commitment of an engineering undergraduate degree (Silbey, 2015). Students are also less likely to engage in cocurricular opportunities due to the pressure they experience due to the requirements of completing an undergraduate engineering degree in four years and the consequences of taking additional time (Geyer & Loendorf, 2015; Ktoridou & Eteokleous, 2014).

The following section briefly details each area in Figure 12, starting with curricular programs driven by NGO's.

NGO-Driven Curricular Programs.

These programs tend to be developed by non-government organizations (NGO), who then partner with universities to deliver the course. In this way, the cultural/contextual expertise of the NGO is made available to the university or instructor while the instructor utilizes the support from the partner in a way that is consistent with the curricular design for the class they teach. The EWB Challenge is an NGO driven curricular program that was founded by EWB-Australia in 2007, and today the EWB Challenge is an educational program embedded into the curriculum at 52 universities around the world, including the mid-sized, western U.S. university referenced

in this study. The program works with a different community around the world each year to use engineering design courses to crowdsource ideas for that community. In past years, the EWB Challenge has included developing innovative and sustainable project ideas to support communities in India, Cambodia, East Timor, Nepal, rural Australia, Vietnam, Zambia, and Cameroon (Cook, Siller, & Johnson, 2016; Cutler, Borrego, & Loden, 2010; Mattiussi, 2013). Other similar programs are the Wicked Problems in Sustainable Engineering initiative (Hess, Aileen, & Dale, 2014), which develops sustainability projects based on the Initiate, Design, Execute, Assess, Learn, & Show (IDEALS) framework (Davis et al., 2011) or the Life Cycle Analysis + University (LCA+U) which teaches students to conduct a life cycle analysis of areas or process on their campus and propose less impactful alternatives (Dale et al., 2014), both of which were created and are supported by Engineers for a Sustainable World. Engineering World Health has a similar model to EWB-USA, with student chapters at universities across the US and projects with partners in developing countries to allow engineering students to use their skills to keep medical equipment in developing countries serviceable (Engineering World Health, 2016). EWH has developed curriculum at the elementary, secondary, and college/university level that can be adopted by American partner universities (Malkin & Calman, 2014). In Canada, EWB Canada partner with universities to develop global engineering certificate programs that have both curricular components and service learning through involvement in the universities EWB Canada student chapter.

University-Driven Curricular Programs.

These programs are created by universities, often in connection with one or more NGO partners, and have some curricular component, although they may include cocurricular components as well. Programs in this area vary in depth from entire departments, such as the

Global Engineering program at Purdue University, which encompasses study abroad programs, global engineering courses, research and internship abroad opportunities, community service programs and global engineering design student symposiums engineering minors (Huff, Zoltowski, & Oakes, 2016; Jesiek, Dare, Thompson, & Forin, 2013; Moses, 2017; Zoltowski & Oakes, 2014). Similarly, D-Lab at the Massachusetts Institute of Technology has grown from a single class, to a large department incorporating fifteen classes, social entrepreneurship mentoring, field training, global co-design summits and research partnered with NGO's and governments across the world (Cook & Thomas, 2012; Murcott, 2016; Technology, 2015). Programs often grow out of a single class, such as the "Engineering Cultures" course taught at Virginia Tech which was adopted by Colorado School of Mines and has since grown into a humanitarian minor program (Lucero & Turner, 2014), or the global engineering program and the Mortenson Center in Engineering for Developing Communities (MCEDC) at the University of Colorado which were originally founded by Dr Bernard Amadei, also the founder of EWB-USA and focused on graduate programs and research, but in 2009 expanded to create an undergraduate track and certificate program (Amadei & Sandekian, 2010; Sandekian, Chinowsky, & Amadei, 2014). Smaller scale interventions are also possible, with the University of Pittsburgh offering an option in their capstone engineering class to allow students to gain international experience through including service learning based challenges (Budny, Arjmand, & Sanchez, 2015) and the University of Puerto Rico has a graduate research program focused on appropriate technologies for partner communities and organizations, which allows upper-level undergraduates to have the option of taking the graduate level "Appropriate Technology: Towards Sustainable Wellbeing" class (Papadopoulos et al., 2014).

Cocurricular Programs.

These are programs that are housed at universities but do not have a curricular component, such as volunteer organizations, alternative spring breaks, Greek life, and other programs that are designed to provide service opportunities for students. Some alternative breaks and service learning opportunities have some level of instruction/reflective practice built into the model, but many do not, which can lead to students learning or reinforcing paternalistic and ethnocentric attitudes (Piacitelli, Doerr, Porter, & Sumka, 2013).

One of the most popular and well-known engineering cocurricular programs is Engineers Without Borders (EWB) USA, an NGO with volunteer student chapters at most engineering colleges across the United States. This is a cocurricular model that has a mix of operative models; in most universities it is detached from the curriculum, operating as a student club with some level of professional oversight from a local professional engineer or engineering instructor at the university. This operative model creates issues that resonate with many of Suchdev et al.'s (2007) criticisms of such projects, such as ineffective and inappropriateness of design, self-serving and unaccountable project teams, the imposition of burden on host communities along with raising of expectations; however, students' self-efficacy related to their global engineering competency increases through involvement with the organization (Litchfield & Javernick-Will, 2014). EWB-USA has implemented a quality control system on the projects to develop a minimum standard for projects and to provide the students with feedback on the project design and implementation (Sacco & Knight, 2014).

Some universities have recognized Suchdev et al.'s (2007) criticisms and built a curriculum around their EWB chapter to provide more support to the students. For example, Rowan University has included their chapter's EWB projects as options in the design project

course as service learning options. They believe this supports the chapter in developing the best solution rather than accepting the first choice and creates a more reflexive, holistic learning experience (Everett, Mehta, Wyrick, & Perez-Colon, 2009), moving their student's involvement with EWB-USA towards a university-driven, curricular model.

Other than engineering specific programs such as EWB-USA, there are other opportunities that are open to all students that engineers may choose to join. Organizations such as the Sierra Student Coalition which supports around 14,000 students to act as climate change activists on their campuses (Karpf, 2010) and widely known NGOs such as Médecins Sans Frontières/Doctors without Borders have active campus groups at medical schools. There are sustainability and human and animal rights student organizations such as the Oxfam Clubs, which now has student groups at over 130 campuses across the United States (Oxfam, 2011). A recent study uncovered that nearly 40% of veterinary medicine students volunteer up to ten hours a week with, mainly, animal-related causes (Kogan & Schoenfeld-Tacher, 2005). For comparison, less than 2% of engineering undergraduate students volunteer with Engineers Without Borders USA, the largest service organization for engineering students (Engineers Without Borders USA, 2017; Yoder, 2016). While both veterinary medicine and engineering have high levels of academic requirement and stress (Silbey, 2015), veterinary medicine has strategically connected students studies to service learning and volunteering (Stevens & Gruen, 2014) to overcome disengagement issues similar to those experienced in engineering (Cech, 2014), by keeping students connected to their motivation for studying veterinary medicine – working with animals.

The EWB Challenge program

The Engineers Without Borders (EWB) Challenge is part of the broader EWB goal of a transformed engineering sector in which every engineer has the skills, knowledge, experience, and attitude to contribute toward sustainable community development and poverty alleviation as well as an understanding of the responsibility of engineers as global citizens (Cook & Howard, 2012). In this way, humanitarian engineering uses a human-centered approach to improving community health, well-being, and opportunity. Each year, the EWB Challenge design brief is based on a set of sustainable development projects identified by EWB-Australia with community-based partner organizations (Mattiussi, 2013). In past years, the EWB Challenge has included developing innovative and sustainable project ideas to support communities in India, Cameroon, Zambia, Cambodia, East Timor, Nepal, rural Australia, and Vietnam.

The program runs within existing university first-year engineering classes and can be adapted to fit course duration, engineering disciplines covered, and credits awarded, as these, along with the class objectives, are still at the discretion of the administering faculty. Effectively, the EWB Challenge provides the context while the university faculty continues to provide the content. The methods used to create a very flexible and appropriate education model that has been used for everything from one-week design crash courses with 1500 students to full-semester or year-long design classes (Cook & Howard, 2012). Engineers Without Borders-Australia founded the EWB Challenge in 2007. Today the EWB Challenge is a sophisticated program embedded into the curriculum at 52 universities in Australia, New Zealand, the United Kingdom, Ireland, Malaysia, and Dubai, reaching over 10,000 students each year. The EWB Challenge has sparked dialogue among academics regarding sustainability and global development engineering education (Cutler et al., 2010; Mattiussi, 2013; Willicks et al., 2017)

and has been the subject of a collaborative Australian Government Learning and Teaching Council research project grant (Cutler et al., 2010). In the UK and Australia, the program provides training for academics to support their personal development and ability to support the students learning through the EWB Challenge. In the UK, this training is offered as a one day course for academics, introducing them to the country and context of the challenge, and engages them in seeing engineering in developing countries through a holistic, systematic mindset (Mattiussi, 2013).

In the class included in this study, the EWB Challenge allowed students to co-create engineering solutions and management strategies to challenges faced by the community living in the Mayukwayukwa refugee settlement in the Kaoma District of Zambia's Western Province. The project partnered with a local NGO supporting the community's transition to a permanent settlement, the UN (United Nations) Refugee Agency (Zambia). The EWB Challenge has been piloted at the mid-sized, western U.S. university for the past two years and was investigated as part of a previous study (Cook et al., 2016). This year was its first implementation as part of the Civil and Environmental Engineering first-year curriculum, having previously been utilized as part of a general engineering first-year class. The EWB Challenge Design Course is taught in the spring semester and follows a one-semester fall Traditional Introductory Course. The Traditional Introductory Course, which acts as the comparison group in this study, is traditionally taken in the first semester of the first year and focuses on helping students build an understanding of the role and responsibilities of engineers. The instructor for both classes in this study is the same individual, a professor in civil and environmental engineering with an academic and professional background in civil engineering. The instructor has significant experience with professional and global competency, having, as part of an NSF 'Revolutionizing

Engineering Departments' grant, led an engineering department in the development of engineering degree courses that integrate professional competence throughout the program. The instructor has also led study abroad programs to international destinations and has written extensively on global engineering and engineering for sustainable engineering (T. Siller, Rosales, Haines, & Benally, 2009; Thomas J. Siller & Durkin, 2013; Thomas J. Siller, Johnson, & Troxell, 2015; T. J. Siller, Palmquist, & Zimmerman, 1998). This background enables the instructor to support student's development of professional and global competence, as Walther, Kellam, Sochacka, and Radcliffe (2011) identified instructors, and their personal competence, background and personality, as a significant meta-influence on students competency development.

Methods

Participants.

This study took place at the College of Engineering at the mid-sized, western U.S. university between January 2017 and March 2018. All participants were engineering undergraduate students in the College of Engineering, and quantitative data were collected in first-year civil and environmental engineering classes, while the semi-structured qualitative interviews took place in a conference room within the college building. Table 8 describes the two classes in more detail, highlighting their commonalities and differences.

Table 8

First-year Civil and Environmental Engineering class sequence—commonalities and differences

Class	Traditional Introductory course	EWB Challenge design course
Class format	Two 50-minute lectures and a two-hour-and-forty-minute lab per week.	Two 50-minute lectures and a one-hour-and-forty-minute lab per week.
Instructor	One instructor supported by graduate teaching fellow and three graduate teaching assistants	Two instructors supported by graduate teaching fellow and three graduate teaching assistants
Grade Assessment	Midterm and final exams Lab reports, Homework assignments Class participation grades	Final exam Lab reports, Homework assignments Team project and presentation Class participation grades
Guest speakers	Multiple guest lectures and panels from practicing engineers, introducing their sector of the industry. Inclusiveness interventions through acted case studies	One guest lecture introducing the EWB Challenge project
Project	None	EWB Challenge project, the focus of 30% of labs and 15% of lectures
Required reading	No textbooks; current news stories related to engineering	AutoCAD Textbook, current news stories related to engineering

The number of students, the data collection method, and the period for the different study groups is shown in Table 9.

Table 9

Different groups within this study

	Traditional Introductory course		EWB Challenge design course	
Type of Data Collection	Questionnaire	Interview	Questionnaire	Interview
Number of Students	136	8	180	8
Data Collection Period	Fall 2017	Fall 17/Spring18	Spring 2017	Spring/Fall 2017

One-semester first-year traditional introductory course.

All students in this Civil Engineering Introduction: Civil/Environmental Engineering course, which pairs with the EWB Challenge design course to introduce students to Civil and Environmental Engineering, were asked to take the Engineering Global Preparedness Index Questionnaire (see Appendix B) at the beginning of the semester in September 2017, during their lab classes associated with the course. These lab classes take place in a computer lab and so the questionnaire, and IRB consent form (see Appendix F) were given online in Qualtrics. Of the 137 students present in the five lab class sections, all students except one consented to and took the questionnaire. The questionnaire was repeated at the end of the semester in December 2017 as a combined post-test and retrospective pre-test (see Appendix C). Of the 155 students present in the five lab class sections, 99 students (63.9%) consented to and took the post-test and retrospective pre-test questionnaire these numbers are well above the acceptable levels for self-reporting data (Gonyea, 2005). Full details of consents, declared major, and gender demographics are reported in Table 10.

Table 10

Demographics of students in one-semester first-year traditional introductory course

Students who	Pre-test no.	Pre- test %	Post-test no.	Post- test %	Complete Data Sets no.	Complete Data Sets %
Self-Identified as Female	42	30.8	37	33.0	34	34.3
Self-Identified as Male	94	69.2	75	67.0	65	65.7
Majoring in Civil Engineering	81	59.6	74	66.1	65	65.7
Majoring in Environmental Engineering	52	38.2	33	29.5	30	30.3
Yet to declare a major	3	2.2	5	4.4	4	4.0
Total	136	100	112	82.3	99	72.8

At the time the students took the survey, volunteers were also recruited from the traditional introductory course (see Appendix E) for interviews to provide qualitative data related to this learning opportunity. Eight students volunteered, five females and three males, between the ages of 19 and 44 and all eight students were interviewed during fall 2017 and spring 2018. The eight students all had previous international travel or Engineers Without Borders experience as part of the student chapter at the university which suggests a potential bias within this study, with the potential to lead to paralogical legitimation (Lather, 1993; Onwuegbuzie & Leech, 2007) where the researcher uses an atypical situation or group of participants to claim generalizable results. In this study, the data collected in the interviews is used to triangulate and reinforce findings uncovered through the quantitative data (which was collected from all students in the class) to reduce the influence of this potential bias

One-semester first-year EWB Challenge design course.

All students in this civil engineering Engineering Graphics and Computing course, which pairs with the traditional introductory course to introduce students to Civil and Environmental Engineering, were also asked to take the Engineering Global Preparedness Index Questionnaire (see Appendix B) at the beginning of the semester in January 2017, during their lab classes associated with the course. These lab classes take place in a computer lab and so the questionnaire and IRB consent form (see Appendix F) were given online in Qualtrics. Of the 180 students present in the six lab class sections, all students consented to and took the questionnaire. The questionnaire was repeated at the end of the semester in April 2017 as a combined post-test and retrospective pre-test (see Appendix C). Of the 185 students present in the six lab class sections, 167 students (90.3%) consented to and took the post-test and

retrospective pre-test questionnaire. Full details of consents, declared major, and gender demographics are reported in Table 11.

Table 11

Demographics of students in the one-semester first-year EWB Challenge design course

Students who	Pre-test no.	Pre- test %	Post-test no.	Post- test %	Complete Data Sets no.	Complete Data Sets %
Self-Identified as Female	60	33	57	34	44	37
Self-Identified as Male	120	67	110	66	74	63
Majoring in Civil Engineering	132	73	121	72	88	76
Majoring in Environmental Engineering	47	26	41	25	28	22.5
Yet to declare a major	1	1	5	3	2	1.5
Total	180	100	167	95.5	118	64.5

As with the traditional introductory course, at this time student volunteers were also recruited from the EWB Challenge Design course (see Appendix E) for interviews to provide qualitative data related to this learning opportunity. All eight students that agreed to be interviewed were included in this study, five females and three males, aged 18 or 19, were interviewed during fall 2017 and spring 2018. Six of the eight students had previous international travel or Engineers Without Borders experience as part of the university's student chapter.

Materials.

Student surveys, student interviews, and focus groups are seen as credible ways of assessing engineering education (Olds, Moskal, & Miller, 2005) about engineering professional skills and global competencies. It should be noted that developing assessment and evaluation

methods in this area is inherently complex, given the list of areas to be investigated, including ethics, social norms, and global difference along with students' own biases based on culture, racial and ethnic position, socioeconomic status, etc. (Sperandio, Grudzinski-Hall, & Stewart-Gambino, 2010).

Demographic questionnaire.

All participants in the study (those who took part in the pre-, post- and retrospective pre-testing and those who were interviewed) completed a demographic survey, which was adapted from the Engineering Global Preparedness Index instrument described below. This survey asks the participants for their age, gender, racial/ethnic background, generational citizenship, and current engineering major as well as if they have lived, done community service, or studied abroad. One question was added to ask participants if they have been or are involved with Engineers Without Borders USA or another international engineering service organization. This item was added to check for students who may appear in more than one of the groups. For full details of the demographic questionnaire, please see Appendix A.

Engineering Global Preparedness Index questionnaire.

There are only a small number of instruments that have been developed to understand the global preparedness of students, partially due to the ongoing challenges in defining students' preparedness as global citizens. Many of these tools are generally applicable to all students, such as the Global Perspectives Inventory (Engberg, 2013; Engberg & Fox, 2011) that measures global perspectives, the Association of American Colleges and Universities Global learning rubric (Hovland, 2014) or UNESCO's instruments that measure extracurricular and non-formal activities that promote global citizenship education and education for sustainable development (Akar, 2016). One instrument has been developed specifically to understand engineering

students' global preparedness, and as such is written in the language of, and based on scenarios found in, engineering. Having realized that no such measure existed, researchers developed the Engineering Global Preparedness Index (EGPI) instrument as part of a multi-university effort to develop a quantitative measure to study engineering students' preparedness for global workplaces (Ragusa, 2011). The instrument was created to identify the effect of formal and informal education practices and interventions on students' global preparedness and was developed to align with both the National Academy of Engineering's "Engineers for 2020" publication (National Academy of Engineering, 2004, 2005) and the ABET standards (Accreditation Board for Engineering and Technology, 2016). The instrument comprises of four subscales, outlined in Table 12, along with eighteen individual items, all of which are measured on a five-point Likert scale.

Table 12

EGPI Sample Items by Selected Subscales/Constructs (Levonisova et al., 2015)

Subscale/Construct	Sample Index Item
<i>Engineering Ethics & Humanitarian Values</i>	Engineers in my country have a moral obligation to share their engineering knowledge with the less fortunate people of the world.
<i>Global Engineering Efficacy</i>	I believe that my personal decisions and the way that I implement them in my work activities can affect the welfare of others and what happens on a global level.
<i>Engineering Global-centrism</i>	I think my country needs to do more to promote the welfare of different racial and ethnic groups in engineering industries.
<i>Engineering Community Connectedness</i>	To treat everyone fairly, we need to ignore the color of people's skin in our workplaces.

The instrument contains sections focusing on engineering professional skills and, through this, the students self-assess their skill level in the professional and global competency items in Table 13 on a five-point Likert scale, from definitely weak to definitely strong.

Table 13

Students' self-assessment of professional and global competencies (Levonisova et al., 2015)

Items of self-assessment
Communication skills
Ability to work in a team
Experience interacting with someone whose culture is different from my own
Mathematical skills
Knowledge about my own culture
Ability to problem solve
Openness to being challenged or have my ideas criticized
Leadership ability
Ability to see an international problem from someone else's point of view
Knowledge about different cultures
Skill in a language other than English or my first language
Willingness to discuss controversial issues
Academic ability
Social skills and self-confidence

The instrument was utilized as a pre-test (see Appendix B) and a post-test/retrospective pre-test (see Appendix C) to account for response shift bias within intervention models (Howard, 1980).

Semi-structured individual interviews.

The interview protocol used in this study was developed following the format suggested by Jacob and Furgerson (2012) utilizing a question set created as part of a National Science Foundation (NSF) Research in Engineering Education (REE) project, undertaken at three collaborating institutions in the United States (Streiner et al., 2015). This study used the EGPI instrument along with the Global Perspective Inventory (Engberg, 2013; Engberg & Fox, 2011) as part of their protocol.

The semi-structured interviews utilized the following questions from the Streiner et al. (2015) study:

- Why did you choose to study engineering (and to go to <country or class/program>)?
- Did the <class or program> change the way you think about engineering?
- Did this <class or program> affect your thinking about the cultural relevance of engineering?

One additional question was added to the protocol to match the aims of this study:

- Do you think your <class or program> has had any effect (positive or negative) on your non-technical engineering skills, such as teamwork, communication, leadership, and global and cultural adaptability?

All questions were shared by email with the interview participants before their interviews, for full details of the interview protocol please see Appendix H.

Issues with Response Shift Bias

Most qualitative measures of global preparedness or awareness are student self-efficacy based, which may call into question the level of ability of students to self-assess given their respective levels of experience. As an example, a recent study into the EWB-USA chapter at the University of Colorado, Boulder, found that members of their student chapter perceived (through self-efficacy surveys based on the ABET criteria) themselves to have fewer technical skills than their peers that had not been involved in the chapter, but greater broad and holistic skills such as ethics, management, finance, and communication (Litchfield, Javernick-Will, & Knight, 2014). The authors suggested that this is due to the contexts and “real-world” application of skills that the EWB chapter members have experienced when compared with their peers who may not have applied their learning non-academically.

This also demonstrates the issue of response shift bias within intervention models (Howard, 1980) whereby the intervention causes the participants to reevaluate the basis of their pre self-evaluation. With a pre-test/post-test evaluation model, participants will shift their responses on the post-questionnaire based on the new knowledge or levels they have developed through the intervention, without having the opportunity to amend their pre-responses, which often uncovers pre-test overestimation (Pratt, McGuigan, & Katzev, 2000). Adding a retrospective pre-test to the post-test allows participants to self-evaluate their change through the intervention, which, if a pre-test was also performed, can be used to check and shift their initial responses to match the participant's post-intervention levels (Hill & Betz, 2005). There are, however, some issues with using retrospective pre-tests, namely that they can increase participants' desire to show change and they introduce threats to validity such as memory recall, history, and regression toward the mean (Lamb, 2011). Despite these issues, retrospective pre-tests in tandem with post-testing are seen as the best practice to control response shift (Drennan & Hyde, 2008) bias and so, within this study, the EGPI instrument is used as both a pre-test and as a combined post-test and retrospective pre-test to account for response shift bias.

Procedures

This procedure was repeated in the EWB Challenge design course in the spring 2017 semester and the traditional introductory course in the fall 2017 semester. Following IRB approval, the Co-PI joined the lab class sections in this course (six sections in total in the EWB Challenge design course and five sections in the traditional introductory course) for the final 20 minutes of the second lab of the semester. The instructor (and PI on this project) was asked to leave the room to ensure confidentiality for the students and to clarify any perceptions of bias or coercion about class grades—completion of these questionnaires was not grade related. The Co-

PI read the approved script (see Appendix E—Verbal Recruitment Script for Use in Classrooms) and directed the students to a link that would open the instruments (see Appendix A for demographics questionnaire; see Appendix B for the EGPI Instrument—Pre-test) and the survey consent form (see Appendix F—IRB Approved Consent Forms). Paper copies were provided for those preferring the paper medium to completing the survey on the computer or their device or cell phone; students were given 20 minutes to complete the instruments. This procedure was repeated two weeks before the end of the semester utilizing the EGPI post- and retrospective pre-test instrument (see Appendix C—EGPI Instrument—Post-test and Retrospective Pre-test).

The participants' student identification numbers were required by the survey (to link pre- and post-questionnaires), but no other identifying information was collected. The student identification numbers were removed and replaced with codes by the Co-PI, and results were not shared with the PI until after all the class grading was complete.

The three sets of data collected for each course were compared to their corresponding data sets from the other course (i.e. pre-data sets for both courses was compared to each other). Within each course, the three sets of data were compared (i.e. the pre-data set were compared with the post and retrospective-pre-data sets in the same course). Comparisons were also made of the four subscales within each data set, following the same comparison configurations.

Within these groups, the data were subdivided based on the demographic data collected (see Appendix A for the Demographics Questionnaire), which allowed for checks of differences and similarities in change based on age, gender, racial/ethnic background, generational citizenship, and current engineering major, as well as if respondents have lived, done community service, or studied abroad or have been involved with the EWB-USA student chapter. The pre, retrospective pre (R-Pre), and post data for both classes were extracted from Qualtrics into Excel

to be cleaned and combined into a complete data set; the data sets were then converted into SPSS files, and the demographic data was added to each item as metadata.

Interview data were transcribed and although interviewee transcript reviews do not tend to add to the accuracy of the transcript but can lead to the loss of data through the interviewee choosing to remove data (Hagens, Dobrow, & Chafe, 2009), member checking was utilized to check for credibility as part of the validity of the data. The interviews were transcribed in Nvivo and analyzed using the Qualitative Content Analysis (QCA) framework (Roberts, 2000), being coded by two independent coders using the sub-constructs from the EGPI instrument. Allowing codes to emerge from the data enabled the quantitative data to act as a support to themes generated through the interviews and those proposed by the EGPI subscales. Once the codebook was established (Appendix G), all interviews were re-coded by both coders using this standard set of codes (themes/patterns/clusters in Table 14) to ensure consistency across all the interviews and an interrater reliability analysis using the Kappa statistic was performed to determine consistency between coders.

These themes, the codes, and data were used to describe the different engineering design project models and to make comparisons between the models based on the demographic similarities and differences as described previously in the quantitative section. This is an iterative process, visualized in Figure 13, in which meaning is derived from many iterations of the analysis (Bazeley, 2013).

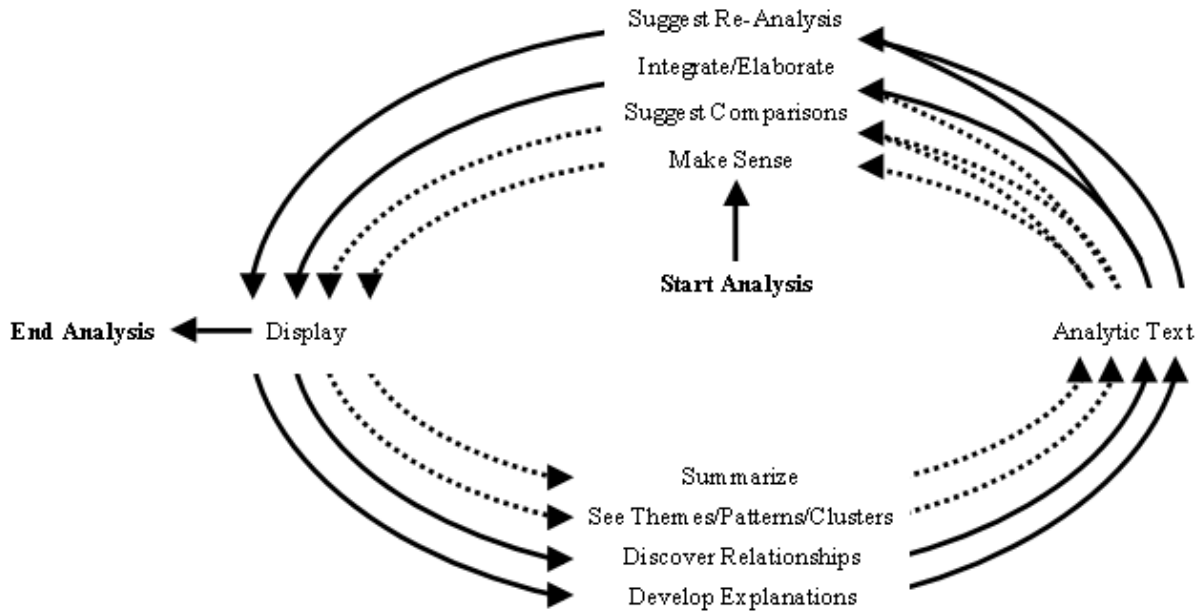


Figure 13 Interactions between the display and analytic text. Adapted from *Qualitative data analysis: an expanded sourcebook*, Miles, Huberman & Saldana, 1994, Thousand Oaks, CA. Sage Publications. Copyright 1994 by Sage Publications

The themes/patterns/clusters and relationships derived from the analysis of text are shown in Table 14, which were utilized to code and recode the text before the final analysis and development of the results.

Table 14

Coding developed from analysis of text

Relationships	Themes/Patterns/Clusters
Global Skills and Competencies	Community Service, working with local communities Foreign Languages, language barriers Reflections on cultural relevance of engineering Global and cultural awareness Global, international, transnational Working with diverse teams, communities Global Citizenship
Professional Skills and Competencies	Teamwork Communication Ethics Leadership Innovation and Entrepreneurship Project Management Other non-technical skills
Impacts and Differences	How EWB, study abroad or class has impacted how you think about engineering Has international travel affected them, differences they noticed Different styles of teaching and learning Reflections on gender in engineering
Student career and study choices	Why students chose to study engineering Why students chose to study abroad Why students chose to join EWB Students future career or study plans

Validity

Principal axis factor analysis with varimax rotation was conducted to assess the underlying structure of the forty-one-item global preparedness portion of the EGPI instrument and to confirm the validity of the four subscales within the instrument design for both sets of data. Firstly, assumptions were tested and demonstrated through the Bartlett test and correlation

determinant that all three tests for both sets of data were correlated highly enough to provide factors but that collinearity within the data would not be an issue. The Kaiser-Meyer-Olkin measures for each test were greater than 0.7, demonstrating that there would be enough items predicted by the four factors to validate the sub-scales. The percentage of variance accounted for by each subscale with each of the three tests for each set of data is outlined in Table 15.

Table 15

Percentage of variance accountable to each subscale within the three tests in both classes

Subscale within the instrument	Amount of variance accountable %					
	Traditional Introductory Course			EWB Challenge Design Course		
	Pre-test	R-Pre-test	Post-test	Pre-test	R-Pre-test	Post-test
Engineering Efficacy	11.37	20.40	20.26	12.17	16.64	15.42
Engineering Ethics	8.63	10.78	10.22	10.45	11.76	11.32
Engineering Global-centrism	5.96	4.73	5.78	5.40	5.02	6.94
Engineering Community Connectedness	5.40	4.17	3.51	4.45	4.33	3.99
Total	31.36	40.08	39.77	33.02	37.76	37.67

After determining the four subscales to be valid within this data, Cronbach's alphas were computed to assess if the data from the items in each subscale are reliable. The alpha for subscales within each test in both classes, the Traditional Introductory course and the EWB Challenge design course, are shown in Table 16. From this table, all the subscales were reliable other than engineering global connectedness, which only indicated minimal reliability on both courses' pre-tests and the EWB Challenge design course post-test. For comparison, Cronbach's alphas from development and initial validation of the instrument (Ragusa, 2011) are included.

Table 16

Reliability coefficients for subscales on EGPI instrument data sets

**Note—items below 0.7 reliability coefficient are not considered acceptable and are not included in overall reliability*

Subscale Efficacy	Cronbach's Alphas								
	Instrument Validation (Ragusa, 2011)	Traditional Introductory Course				EWB Challenge Design Course			
		Pre	R-Pre	Post	Avg.	Pre	R- Pre	Post	Avg.
Engineering Ethics	.79	.87	.92	.91	.90	.88	.89	.90	.89
Engineering Efficacy	.70	.79	.86	.86	.83	.84	.85	.82	.84
Engineering Global- centrism	.68	.80	.87	.86	.84	.74	.75	.83	.77
Engineering Community Connectedness	.69	.68	.81	.80	.76	.66	.73	.68	.69
Overall Reliability	.77	.78	.86	.86	.84	.78	.81	.81	.80

External validity was confirmed through triangulating the findings from the EGPI

instrument to the codes developed through analysis of the interviews with students in the two classes who undertook the EGPI. While not explicitly measured, the comparison between the two courses is seen as reliable as the classes are both typically taken by students in the first year of the civil engineering curriculum and are designed to be taken in sequence, with the Traditional Introductory Course in the fall and the EWB Challenge Design Course in the spring of the first year. The research was designed so that the students did not repeat the instrument (i.e., the students in the Traditional Introductory Course were not the same students in the EWB Challenge Design Course). The coded transcripts were checked for inter-coder reliability, giving a kappa score of 0.66, which demonstrates acceptable agreement between coders (Landis & Koch, 1977).

Results

Response shift bias.

The students' responses demonstrated the issues of response shift bias as can be seen in Table 17. The students' mean response dropped by 0.29 between their pre-test responses and their retrospective pre-test responses in the Traditional Introductory Course and 0.22 in the EWB Challenge Design Course, demonstrating that they probably gained a greater understanding of the question and their relative response level through the period of the course, given the inherent issues with retrospective pre-tests highlighted in the issues with response shift bias section earlier in this article. The importance of this is demonstrated by the comparable difference for the four subscales between the post-test mean scores and the pre-test or retrospective pre-test responses. Comparing the students' mean post-test responses against their pre-test responses would have resulted in a drop across all four sub-scales in both classes.

Table 17

Mean & standard deviations of student responses to tests

Subscale within the instrument	Traditional Introductory Course						EWB Challenge Design Course					
	Pre-test		R-Pre-test		Post-test		Pre-test		R-Pre-test		Post-test	
	Mea n	Std. Dev	Mea n	Std. Dev	Mea n	Std. Dev	Mea n	Std. Dev	Mea n	Std. Dev	Mean	Std. Dev
Engineering Efficacy	3.98	.87	3.78	.98	3.94	.92	4.08	.86	3.86	.98	4.02	.97
Engineering Ethics	3.79	.90	3.57	.98	3.66	1.00	3.84	.94	3.59	1.06	3.71	1.08
Engineering Global-centrism	3.86	.89	3.66	.95	3.82	.94	3.94	.92	3.72	1.01	3.87	1.03
Engineering Community Connectedness	3.99	.90	3.80	.96	3.91	.98	4.02	0.93	3.84	1.02	4.00	1.01

By comparing their retrospective pre-test responses, positive change is seen instead across all four subscales; however, within the sub-scales, sixteen of the forty-one items did not demonstrate a significant ($p < 0.001$) change. As shown in Table 18, paired samples t-tests on

each subscale for the two classes indicated that while there is a statistically significant difference between most items on the subscales in both classes (between retrospective pre-test and post-test results). For the four subscales in both classes $d = .15$ to $.21$ the average difference or change between retrospective pre-testing and post-testing is statistically small according to Cohen's (1988) guidelines.

Table 18

Paired samples t-test results for changes between retrospective pre-test and post-test (significance level $p > 0.001$)

Subscale within the instrument (no. of items in scale)	Traditional Introductory Course					EWB Challenge Design Course				
	<i>t</i> (98)	<i>p</i>	<i>d</i>	<i>Max d</i>	No of sig. items	<i>t</i> (117)	<i>p</i>	<i>d</i>	<i>Max d</i>	No. of sig. items
Engineering Efficacy (25)	1.78	.21	.18	.34	22	2.17	.12	.20	.29	17
Engineering Ethics (22)	1.63	.23	.16	.34	16	1.85	.18	.17	.29	18
Engineering Global-centrism (16)	1.70	.22	.17	.29	13	2.07	.16	.19	.29	12
Engineering Community Connectedness (13)	1.50	.25	.15	.34	12	2.30	.02	.21	.29	8

No statistically significant difference was found between the classes after analysis of variance (based on the change between retrospective pre-test and post-test) as all significance levels for the four subscales p was much greater than 0.05. An analysis of co-variance utilizing one-way ANCOVA tests were conducted to check if there was a significant difference of gain between the two classes on the four subscales after controlling for gender, age, engineering major and if the student had previous international experience and similarly, no significant difference was found as all tests resulted in scores of $p > 0.05$.

Differences in global preparedness.

An independent samples t-test indicated there was no significant (at significance level $p > 0.05$) gender difference in gain between the retrospective pre-test and post-test on any of the four sub-scales in either class as can be seen in Table 19.

Table 19

Comparison of students grouped by self-reported gender, based on gain between retrospective pre-test and post-test responses by sub-scale

Subscale	Traditional Introductory Course (N = 34 female and 65 male)						EWB Challenge Design Course (N = 44 female and 73 male)					
	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>
Engineering Efficacy			.99	97	.33	.50			-.06	116	.60	.03
Female	4.79	6.11					7.82	5.32				
Male	3.58	5.88					7.89	7.07				
Engineering Ethics			1.47	97	.23	.63			.57	116	.61	.25
Female	2.35	4.40					2.70	4.11				
Male	1.06	4.01					2.16	5.47				
Engineering Global-centrism			1.40	97	.06	.59			.13	116	.93	.05
Female	3.12	4.30					2.32	3.60				
Male	1.92	3.89					2.22	4.20				
Engineering Community Connectedness			1.41	97	.22	.48			.29	116	.85	.10
Female	1.94	2.95					2.25	3.15				
Male	1.15	2.45					2.07	3.29				

It is interesting however that female student's self-reported significantly higher levels across all four subscales on post-tests in both classes as is demonstrated in the totals (not gain) reported in Table 20.

Table 20

Comparison of student's post-test responses by sub-scale, grouped by self-reported gender

Subscale within the instrument	Traditional Introductory Course				EWB Challenge Design Course			
	Female (n=34)		Male (n=65)		Female (n=44)		Male (n=73)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Engineering Efficacy	102.91	12.57	96.18	12.99	105.30	13.34	97.53	13.57
Engineering Ethics	76.79	11.49	70.77	9.06	79.32	11.04	71.23	11.17
Engineering Global-centrism	60.24	8.24	55.65	8.01	61.91	8.63	55.70	8.33
Engineering Community Connectedness	53.03	6.77	49.75	6.83	54.41	6.66	50.66	6.69

Similar results were found for students who had previous international travel experience through living, studying, or undertaking community service abroad. There was little or no difference between classes in the gain the students reported in global preparedness or any significant difference (at significance level $p > 0.05$) between students with or without previous international experience as can be seen in Table 21.

Table 21

Comparison of students grouped by international experience, based on gain between retrospective pre-test and post-test responses by sub-scale

Subscale	Traditional Introductory Course (N = 28 with previous international experience and 71 without)						EWB Challenge Design Course (N = 38 with previous international experience and 79 without)					
	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>
Engineering Efficacy			-.69	97	.71	-.37			.19	116	.60	.10
With	3.35	6.33					8.02	5.49				
Without	4.25	5.58					7.78	6.88				
Engineering Ethics			1.06	97	.24	.47			.32	116	.99	.14
With	2.21	5.24					2.58	4.38				
Without	1.23	3.67					2.26	5.28				
Engineering Global-centrism			-	97	.24	-.44			-.28	116	.32	-.11
With	1.67	4.98	1.01				2.11	3.44				
Without	2.59	3.64					2.33	4.22				
Engineering Community Connectedness			.43	97	.62	.16			-.26	116	.75	-.09
With	1.61	2.71					2.03	3.19				
Without	1.35	2.64					2.19	3.26				

However, students in the EWB Challenge Design Course had a mean gain in engineering efficacy that was more than three times that of the other subscales and approximately twice that of the comparable engineering efficacy gain reported in the Traditional Introductory Course as can be seen in

Table 22, demonstrating the impact of the EWB Challenge project on students engineering efficacy.

Table 22

Mean gain between retrospective pre-test and post-test by sub-scale for both classes in this study

	Traditional Introductory Course Mean gain	EWB Challenge Design Course Mean gain
Engineering Efficacy	4.00	7.86
Engineering Ethics	1.51	2.36
Engineering Global-centrism	2.33	2.26
Engineering Community Connectedness	1.42	2.14

This finding was supported by the interviews with students in both classes; those in the Traditional Introductory Course reflected that the class had helped them build an understanding of the role of an engineer and their place in engineering:

I think [the instructor] does a great job of getting you thinking and its more about, trying to figure out which engineering you like better between civil and environmental, what they do in the world, how that connects with what you want to do in the future and I think it's great cause I'm listening to all these ideas and I'm thinking, man, I don't want to do any of this! So, I think it's useful in that sense, so for me it's been great because it's just all that listening and how your degree can relate to what you want to do in the future and you can see well, that's not what I want to do or yes, that's what I want to do.

Students in the Traditional Introductory Course also reflected on the non-typical nature of the class, comparing it to the introductory classes their peers are undertaking in other engineering disciplines:

It's funny talking to other engineering majors who are in, you know, they're spending hours studying, and I'm not as much but, in a way I find it almost more beneficial because to them it seems like their engineering courses are pushing them away from engineering versus mine just seems to be more welcoming and so, even if I'm not

necessarily learning strictly as much I'm learning how to think like an engineer, how to be an engineer I guess.

Whereas students in the EWB Challenge Design Course reflected on how the class had helped them to expand this abstract understanding of engineering to outside the United States:

It was cool to learn that like civil engineering can reach out to like, developing countries cause I kind of like just thought of it as infrastructure in the U.S. or like, I don't know, bigger countries, I didn't think about how we reach um, yeah, the developing world and what we can do to benefit them.

The course also helped them to connect engineering to social impact and the real-world limitations placed on the engineering field:

I thought it was very, mind-opening, definitely, widened my horizons, helped me widen my horizons. Uh, we looked at several projects and uh, saw how people were suffering because they don't have the same privileges we have here, I mean in the U.S. and, generally wanted to help to inspire us to be more grateful for what we have and try and come up with a solution that was feasible, given the requirements for the challenge.

This is reflected in general in the students' discussion of professional skills, such as ethics, teamwork, communication, entrepreneurship, leadership, and project management. In the Traditional Introductory Course, twice as many students (6 students with 11 coded, unique references compared to 3 students in the EWB Challenge Design Course with 5 coded, unique references) talked about the ethics and leadership components of engineering in abstract terms, many quoting the instructor's use of the phrase "do the right job and do the job right" as their main take away from the class. Students also discussed professional skills as an abstract idea,

and are unsure of how professional skills can be taught in classes, with one respondent even identifying that student organizations/clubs and cocurricular learning are where they expected to learn these skills, rather than in engineering classes:

I don't know if there is a great way to just lecture about [professional skills] though, they're kind of those skills where you just need to jump in and so I don't know if that would be involved with a class that just encourages you to go and find something you're passionate about and make a project up and do it or if it's just, would just be some sort of requirement to engage in extra-curriculars or something but whatever it may be it should be encouraged because sooner or later you're going to have to engage in them no matter what you do in life so, the sooner, the better.

All eight of the students in the EWB Challenge Design Course, on the other hand, talk about the practicalities of working in engineering teams, focused on the teamwork and communication aspects of professional skills, and their learning through the teamwork aspect of this class (all 8 students with 28 coded, unique references compared to 5 students in the Traditional Introductory course, with 8 coded, unique references), as they develop their engineering efficacy:

It's not always just, yeah, just go and build them some houses. Okay, out of what?

Using what materials, under what cost constraints and everything like that so it was, it was very interesting to view, you know, a real-world problem with those filters and, start that dialogue of how, not everything is always just go buy it, just pay for it, just do this, just do that. We live in a modern industrial nation where, if you work on a construction project for Hansel Phelps and they're like "we need rebar, go buy it" buy rebar, you know, put in a purchase order and buy rebar. We need to build a retain, we, this

foundation is softer than we thought it was, we're going to have to excavate and build a retaining wall, okay, there's a cost associated with that but for the most part, it's not a question of whether or not we can do it, it will be done and it's a question of cost. This is a question of what can we do, we're under specific constraints and I think that's a very important way to look at things, because we don't always have infinite resources, we have finite things and we've got to learn to work with those things because if you can learn to do that, you can learn to tackle the larger problems that we have.

While some students focused explicitly on the global aspect of the project and how different engineering might be in other countries:

I've kind of learned that that can be the hard part of engineering when you're trying to do it in developing countries, put in your own ideas when it's maybe not part of what, like who they are as a country and what they're used to. Um, it kinda helped me learn the challenges and like, also like the ethical aspects that you deal with that I didn't think you would in engineering, cause you just think about like math, and like the numbers and building it and you don't think about the people so, this project kind of opened me to that a little bit.

Students, having taken this class, recognize the importance of experiential learning and that the concrete experiences they go through as part of a project help them to learn:

Homework I feel like they don't really provide the proper motivation I feel like projects are the way to go as far as experience is concerned.

While these classes are traditionally taken by most students in their first year in engineering, there are a number (6 in the Traditional Introductory Course and 13 in the EWB Challenge Design Course) of non-traditionally aged students, who by the end of their respective

courses were 21 or older. While these classes do not provide the same degree of increase in the subscales global preparedness for non-traditionally aged students as they did for traditionally aged students, this pattern was reflected in both classes, and the difference between gains was very similar however it should be noted that Levine's test found no significant difference in gain between the traditionally aged and non-traditionally aged students, so the differences between the groups in Table 23 is not statistically significant, at least partially because of the unsuitability of these groups for testing, due to the small n of the non-traditionally aged groups.

Table 23

Comparison of traditionally and non-traditionally aged students based on gain between retrospective pre-test and post-test responses by sub-scale

Subscale within the instrument	Traditional Introductory Course				EWB Challenge Design Course			
	21 or younger (n=93)		21 or older (n=6)		21 or younger (n=108)		21 or older (n=10)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Engineering Efficacy	4.15	5.91	1.67	2.42	8.18	6.59	5.31	4.44
Engineering Ethics	1.60	4.27	0.00	1.67	2.48	5.20	1.38	2.63
Engineering Global-centrism	2.42	4.16	1.00	1.55	2.54	4.08	0.00	1.74
Engineering Community Connectedness	1.45	2.72	1.00	1.26	2.29	3.33	0.92	1.85

No non-traditionally aged students were interviewed from the Traditional Introductory Course class, but the non-traditionally aged students interviewed in the EWB Challenge Design Course showed some insight into the difference that their life experience brings to the class. This was particularly evident for traditionally aged students regarding their development of global and cultural awareness through understanding the implications of their designs; this learning seemed more evident to non-traditionally aged students with greater life and/or international experience:

I know there was like one group that was going to build houses out of uh, soda bottles, and that's cute and all, but I don't think so! Yeah, I mean, I, I, my first thought was, what about these people that have to live in these houses and how does that fit in with the culture, I can't imagine that their culture has a whole lot of room for Pepsi bottles.

Students were also asked about their previous experience with Engineers Without Borders USA or other international development service organizations. Eight students in the Traditional Introductory Course and 20 students in the EWB Challenge Design Course had been or were involved with an international development organization. In the Traditional Introductory Course, students who had previous experience reported no real change in their global preparedness through this class, while those with no experience reported some significant improvement as shown in Table 24. In the EWB Challenge Design Course, both groups of students—those with and without experience—demonstrated considerable improvements across all four sub-scales, and the effect size was very large based on Sawilowsky's (2009) scale as shown in Table 24. This suggests that students in the EWB Challenge class gained global preparedness through the course regardless of their previous international experience, while students in the traditional introductory who had previous international development experience, including those involved in the EWB student chapter, did not gain global preparedness.

Table 24

Comparison of students with and without previous international development service experience based on gain between retrospective pre-test and post-test responses by sub-scale

Subscale	Traditional Introductory Course (N = 8 with previous experience & 91 without)						EWB Challenge Design Course (N = 20 with previous experience & 98 without)					
	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>d</i>
Engineering Efficacy			2.07	99	.04	2.22			.29	116	.77	.19
Experience	.00	1.77					8.25	5.74				
No experience	4.35	5.88					7.78	6.60				
Engineering Ethics			1.34	99	.18	1.16			-.06	116	.95	.04
Experience	-.38	1.92					2.30	3.33				
No experience	1.67	4.28					2.38	5.28				
Engineering Global-centrism			1.62	99	.11	1.40			.24	116	.81	.12
Experience	.13	1.73					2.45	3.58				
No experience	2.53	4.18					2.22	4.06				
Engineering Community Connectedness			1.74	99	.09	1.30			-.21	116	.84	.10
Experience	-.13	.99					2.00	2.45				
No experience	1.56	2.71					2.16	3.37				

Professional and global competencies.

Students in both classes were further asked about their abilities in various areas of professional and global competencies, as reported in Table 25. Students in both classes demonstrated significant improvement between their retrospective pre-test and post-test scores.

Table 25

Mean scores of students self-assessment of professional and global competencies (Levonisova et al., 2015)

Item of self-assessment	Traditional Introductory Course			EWB Challenge Design Course		
	Pre	R-Pre	Post	Pre	R-Pre	Post
Related to professional competencies						
Communication skills	3.77	3.41	3.76	3.75	3.69	3.98
Ability to work in a team	4.19	3.98	4.22	4.16	3.97	4.24
Mathematical Skills	3.97	3.89	3.82	4.09	4.03	4.29
Ability to Problem Solve	4.17	3.90	4.18	4.29	4.09	4.36
Leadership Ability	4.07	3.76	3.96	4.04	3.95	4.16
Academic ability	4.02	3.82	4.05	4.20	4.00	4.11
Related to global Competencies						
Experience interacting with someone whose culture is different from my own	4.05	3.89	3.89	3.92	4.11	3.85
Knowledge about my own culture	4.91	3.90	3.86	4.01	3.91	4.05
Openness to being challenged or having my ideas criticized	4.14	3.85	4.14	4.03	3.88	4.26
Ability to see an international problem from someone else's point of view	3.90	3.64	3.75	3.81	3.68	4.04
Knowledge about different cultures	3.51	3.28	3.14	3.10	3.32	3.68
Skill in a language other than English or my first language	2.61	2.59	2.47	2.43	2.46	2.58
Willingness to discuss controversial issues	3.92	3.63	4.08	4.11	3.90	4.09

After calculating the change students reported from the retrospective pre-test to the post-test, an analysis of variance demonstrated that while there is a difference between the Traditional Introductory Course and the EWB Challenge Design Course on all items, the significant difference is generally found on the items of self-assessment related to global competency, not

professional competency, as can be seen in Table 26, none of the items related to professional competencies had a statistically significant difference between classes.

Table 26

Statistically significant differences between classes

Item of self-assessment	df	F	p	Traditional Introductory Course			EWB Challenge Design Course			Total		
				n	M	SD	n	M	SD	n	M	SD
Experience interacting with someone whose culture is different from my own	1,215	5.09	.03	99	.00	1.04	118	.26	.66	217	.14	.86
Knowledge about my own culture	1,215	3.85	.05	99	-.04	.91	118	.14	.42	217	.06	.69
Ability to see an international problem from someone else's point of view	1,215	4.18	.04	99	.11	1.08	118	.35	.59	217	.24	.85
Knowledge about different cultures	1,215	21.51	>.01	99	-.14	.99	118	.36	.56	217	.12	.82
Skill in a language other than English or my first language	1,215	4.14	.04	99	-.11	1.15	118	.13	.50	217	.02	.87
Willingness to discuss controversial issues	1,215	5.23	.02	99	.45	1.01	118	.19	.64	217	.31	.84

EWB Challenge Design Course students reflected on these items during the interviews and they demonstrated a depth of thought around these items beyond learning that item in isolation; for example, this student systematizes their learnings around the importance of language and communication to an understanding that successful engineering, requires supportive community frameworks and education that are appropriate to the community they worked with as part of the class:

I think what we really focused on was not on the compost[ing technology], it's about the system that we're implement[ing], like we're going to be going and educating people about how to use the compost, it's not really about, I mean the compost is just a box and so we're really going to be, there's going to be like, leaders for each street that are going to have like this extra supplies if they need anything and their going to be the ones that we give the materials for in their language and like, if they need or have any questions about the system.

In many ways, students in the EWB Challenge Design Course reflected on how the project had made them aware or more aware of the differences of working as an engineer in different countries, contexts, and communities:

It comes down to cultural aspects and like designing actual stuff there I thought it was interesting how the project was able to kind of introduce you to a, kind of a, ah, kind of give you an intro into how you would deal with other countries you know, with their own set way they do things.

Students recognized the value of this learning and saw it as important, although not as fundamental to achieving an engineering degree as technical competency. Through this project, they observed and reflected on a culture and context very different from their own and begin to formulate conceptualizations of how to be an engineer working with different groups:

I feel like being engineers, we should be able to work with different people groups and uh, I wouldn't say it's a requirement but it's definitely beneficial, and helpful if we can a little bit more adaptive. So, I did some research on the culture and uh, traditions um, even their habits.

Discussion

Projects support students' development of engineering efficacy.

As has been found in other studies (Brake & Curry, 2016; Hirshfield, Chachra, & Finelli, 2015), engineering projects help students build engineering efficacy. Dunlap (2005) found that engineering projects are, in students' opinions, the learning model through which they gain engineering efficacy. The findings from this study demonstrate similar results; as part of the Traditional Introductory Course, students are introduced to many different projects and engineers from different facets of civil and environmental engineering, but through the EWB Challenge project in the EWB Challenge Design Course students self-reported double the gain in engineering efficacy. UNESCO's Engineering System Model (United Nations Educational Scientific and Cultural Organization, 2010) outlined in the introduction to this paper demonstrated the importance of engineering efficacy, understanding the role of engineering within the global system and its connection to society and nature, as fundamental to the future of engineering in terms of global development. A method to strengthen the development of engineering efficacy would be the use of intentional reflective practices throughout and after the EWB Challenge class. Reflection on learning is paramount in experiential learning and in the classes investigated for this study, no intentional reflective practices, to help the students translate their learning from the EWB Challenge to the engineering studies or global and professional competencies (other than the survey and interviews as part of this study) are included in the course design. Reflective practices such as journaling throughout the design project (Gough, Janega, & Dalo, 2018), specific written assignments that help students intentionally reflect on their learning (Wegner, Stefan M. Turcic, & Hohner, 2015) or student discussion groups that reflect on the project and the students learning (Turns, Sattler, Yasuhara,

Borgford-Parnell, & Atman, 2014) should be implemented for all student engineering projects, including the EWB Challenge.

Global development projects support students' development of global awareness.

From responses to the Engineering Global Preparedness Index instrument, students who took the EWB Challenge Design Course reported little or no real change in the engineering ethics, global-centrism or community connectedness sub-constructs of global preparedness compared with the students in the Traditional Introductory Course. However, through the interviews and in the survey responses related to explicit global competencies the students demonstrated that while they may not have developed global preparedness, through this class they had formed abstract concepts and generalizations about the complexities and differences of engineering globally and through the testing and practice in this one project, had made some improvement towards some global competencies. As this is an introductory course, this is a promising outcome of implementing the EWB Challenge that through further development of the class, could support students developing fuller global preparedness.

Global development projects support women's engineering identity.

Finally, previous studies into the gender differences of engineering identity (Eschenbach, Cashman, Waller, & Lord, 2005; Tonso, 1999, 2006) based on Eccles's (Eccles, 1983) expectancy-value theory have uncovered that, generally, female students tend to identify with engineering as a contextualized, human-centered communicative subject (Stout, Grunberg, & Ito, 2016). This would suggest female students would be more engaged with global preparedness due to the human-centered nature of the model, and this study found that female students responded at a higher level than the male students to all four subscales of global preparedness in both classes. This result is also reflected by other studies into engineering for global

development, which finds higher percentages of female engineering students engaging with EWB-USA student chapters (Litchfield, Javernick-Will, & Paterson, 2014) and interest in future careers in international development (Litchfield & Javernick-Will, 2017).

Conclusion and Research Recommendations

This study supports the body of literature that demonstrates the importance of experiential learning opportunities for engineering students in the development of their professional and global preparedness. This study, by comparing two first-year civil and environmental engineering classes, demonstrates the value of the Engineers Without Borders Challenge in creating an experiential learning opportunity for engineering students that support students' development of professional competencies related to working in teams, helps students develop global awareness and engineering efficacy, and aligns with some of the values that, in particular, support women's engineering identity development. Engineering for Global Development is a relatively new lens to use in engineering education, but with the rapid growth of programs developed by universities and other education partners, it is an exciting opportunity for engineering colleges to connect engineering to the values and interests of many engineering students. As one student commented, "I just like the idea and applying the things that I was learning both in [the EWB Challenge Design Course] and really using it as a, a lens to view real-world problems and how we could seriously tackle them". This study demonstrates that it is feasible to integrate global preparedness into existing classes by contextualizing engineering design projects in contexts, cultures and locations that enable students to develop global preparedness by supporting their understanding of engineering within the complexities of reality, rather than the decontextualized norms of engineering curriculum. Engineering instructors can leverage the experience and connections of external partners, such as NGO's like Engineers

Without Borders, to strengthen their courses by partnering with expertise that may not be available to them individually, or within an academic institution. Changing this mentality of engineering education, from a belief that engineering can be taught as a technical subject, in a vacuum with little requirement to understand the realities of engineering practice, to an engineering that is centered in a systematic understanding of context, culture, and the other stakeholders in engineering design and practice is fundamental to the future of engineering education.

An issue, identified in studies of students development of global competency is that many of the programs that engage students in global contexts and cultures include international travel, which due to the financial cost may be exclusionary to many students, outside of the mobile, global elite (Vandrick, 2011). Programs such as the EWB Challenge, and similar programs such as the Engineers for a Sustainable World academic programs (Dale et al., 2014; Hess et al., 2014) or Engineering World Health programs (Engineering World Health, 2016) provide opportunities for students and instructors to bring culturally contextualized programs into their curriculum on campus, without any additional financial barriers. This removes some of the barriers that typically separate first generation, PELL grant recipient (Stroud, 2010; Ungar, 2016) and other traditionally minority students groups in engineering, from experiences where they can gain global preparedness.

These programs also align with and support the goals of supporting diversity and inclusion in engineering education, a movement promoted by the National Science Foundation and UNESCO (Delaine, Tull, Sigamoney, & Williams, 2016). These programs present engineering in different cultures, rather than de-contextualized, or in the dominant culture/context of academia, as is typical of engineering programs. By presenting engineering as

reflective of culture and environment, students are more able to connect their studies to their own interests and culture, making engineering studies more attractive to more diverse students.

Future research could build on the initial findings of this study to compare many of the other programs developed in this engineering for global development area, as outlined in the introduction to this article, to understand their impact on professional and global competencies and preparedness. This study could also be expanded to examine the role of engineering for global development programs in engineering colleges in the development of engineering identity and any differences related to gender, age, or student generation.

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Article 3: Comparing the Value of Different Study Abroad and Volunteer Programs to Engineering Undergraduate Students' Global Preparedness.

Introduction

While it is generally agreed that global preparedness is fundamental to the future and, in many cases, the current success, of all STEM roles (United States Congress Joint Economic Committee, 2012), including engineering (National Academy of Engineering, 2004, 2005), there is a very little research into how different student experiences through curricular and cocurricular classes and programs affect students' development of global preparedness (Streiner et al., 2015). This article explores how student engineering experiences prepare students for working globally, through understanding their growth both in the professional skills and preparedness to work globally, based on the definition of global preparedness for engineering students as provided by the formative work undertaken by Ragusa (2011, 2014). This work led by Ragusa developed an understanding of global preparedness based on four interrelated constructs: engineering global efficacy, engineering global-centrism, engineering global ethics and humanity, and engineering community connectedness (Levonisova et al., 2015; Ragusa, 2014).

As is shown in Figure 144, several researches have created research that developed similar models with specific differences to the model developed by Ragusa (2011). Allert et al.'s (2007) conceptualization of the global engineering profession contains similar technical, professional, and global constructs; however, Ragusa adds global preparedness as an overarching theme that contains the professional and technical skills required to be a global engineer. Jesiek, Zhu, Woo, Thompson, and Mazzurco (2014) development of a global engineering competency model similarly constructs three contextually specific dimensions of competency: technical

coordination, understanding and negotiating engineering cultures, and navigating ethics, standards, and regulations as an engineering practice-oriented conceptualization.

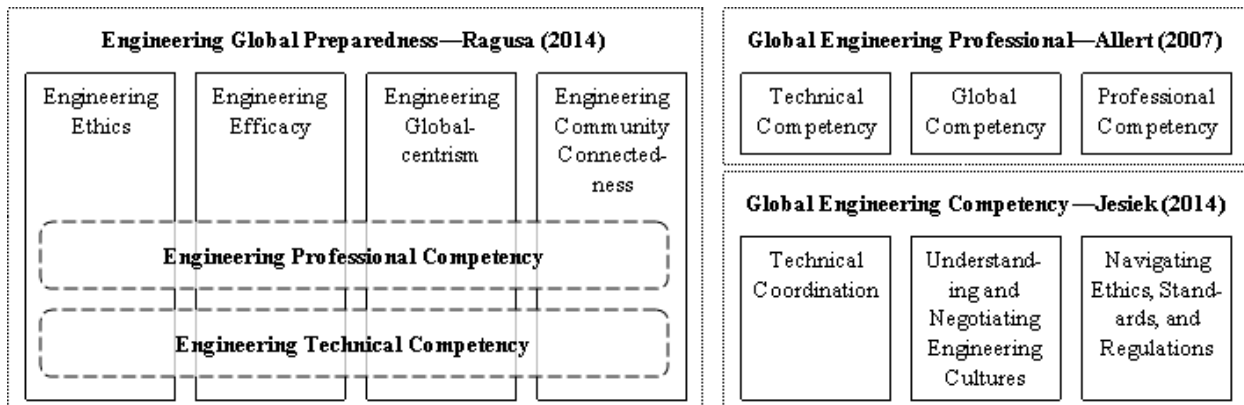


Figure 14. Comparison of different global preparedness conceptualizations from Allert et al. (2007); Jesiek et al. (2014); (Ragusa, 2014)

These three different conceptualizations can be synthesized into a combined model based on Ragusa's (2014) model as shown in Figure 155. This conceptualization demonstrates that despite the differences between the three models the constructs contained within the three different authors' conceptualizations of engineering global preparedness or the global engineer are remarkably similar in content.

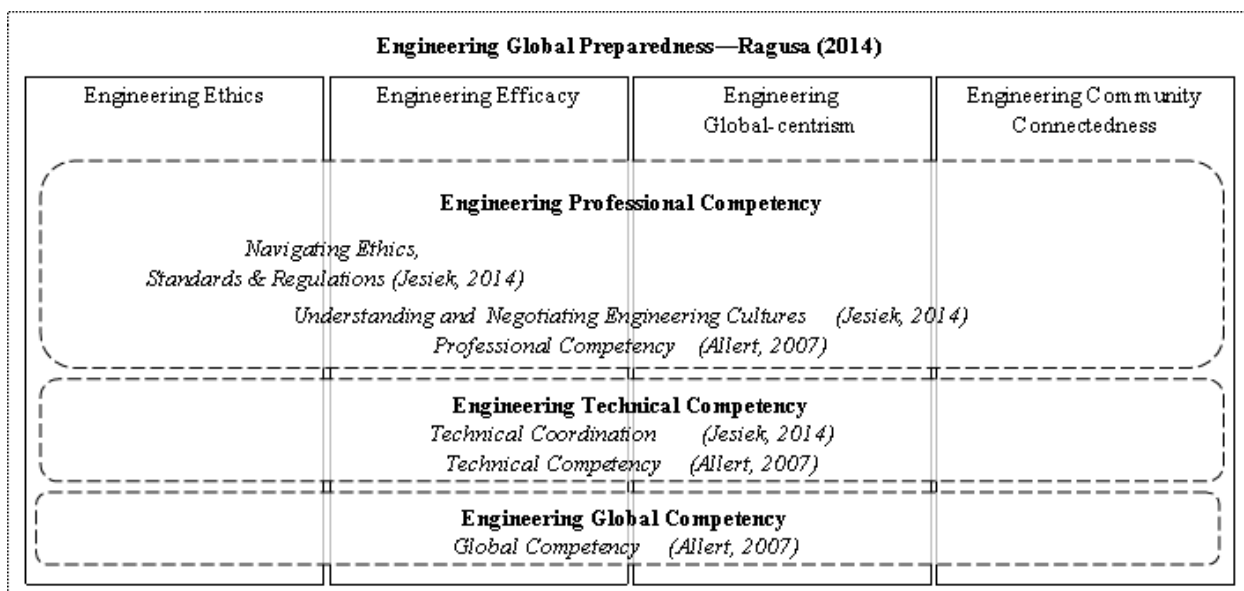


Figure 155. A synthesized conceptualization of three models of global preparedness from Allert et al. (2007); Jesiek et al. (2014), and Ragusa (2014)

The global preparedness constructs are similar to the professional skills needed by engineers, with the addition of global contextualization—that is, the ability of the individual student to apply the professional or technical skill based on differing global socio-economic, political, and cultural realities (Hariharan & Ayyagari, 2016). Table 27 expands on the constructs of global preparedness by synthesizing findings from four global research studies and reports focused on the professional skills needed by global engineers. The American Society for Engineering Education collected student, parent, faculty, and industry perspectives on professional skills for engineers (American Society for Engineering Education, 2013, 2018), and Massachusetts Institute of Technology and Harvard University examined the professional skills seen as required to be a professional engineer in engineering education literature and checked this list by asking their alumni now in engineering management roles to validate the skills (Fisher, 2014). In the United Kingdom, a publication by the Institute of Education and the non-government organization Engineers against Poverty highlighted the skills required by globally competent engineers (Bourn & Neal, 2008), and in Australia the Council of Deans examined the competencies they believe the engineer of the 21st century requires (King, 2008).

Table 27

Subconstructs of EGPI instrument (Ragusa, 2014) with aligned professional skills from four studies

Sub Construct (Ragusa, 2014)	Description (Ragusa, 2014)	Professional Skills (American Society for Engineering Education, 2013, 2018; Bourn & Neal, 2008; Fisher, 2014; King, 2008)
Global Engineering Ethics	A depth of concern for people in all parts of the world, sees a moral responsibility to improve life conditions through engineering problem solving and to take such actions in diverse engineering settings.	Cross-cultural skills, ethics, global awareness, sustainability, disciplinary knowledge, civic responsibility, and professional responsibility
Global Engineering Efficacy	The belief that one can make a difference through engineering problem solving; support for one's perceived ability to engage in personal involvement in local, national, international engineering activities toward achieving greater good using engineering problem solving and technologies.	Critical thinking, civic responsibility, creativity, strategy, problem-solving, global awareness, disciplinary knowledge, innovation,
Engineering Global-centrism	Valuing what is good for the global community in engineering related efforts, not just one's own country or group, making judgments based on global needs for engineering and associated technologies, while not focusing on ethnocentric standards.	Global awareness, sustainability, communication, teamwork, environmental awareness, problem-solving
Engineering Community Connectedness	Awareness of humanity and appreciation of interrelatedness of all people and nations and the role that engineering can play in improving humanity, solving human problems through engineering technologies, and meeting human needs across nations.	Communication, cross-cultural skills, ethics, humanitarianism, problem solving, innovation, teamwork

There are many different student experiences that support engineering students' development of global preparedness and the professional and technical skills required, and the

following section examines the literature to uncover examples of different curricular and cocurricular classes and programs globally working toward this aim.

Review of Literature

Internationalization of engineering students learning environment

Outside the traditional classroom model for engineering learning, there are other types of educational models that help students take steps toward global preparedness, including long- and short-term study abroad, international internships, international field trips, and integrated classroom experiences (Downey et al., 2006). Two studies looked at how these are implemented at universities across the United States and demonstrated the different opportunities available in Table 28 (Grandin & Hirleman, 2009; Parkinson, 2007).

Table 28

Curricular and cocurricular classes and programs for global preparedness

Grandin & Hirleman (2009)	Parkinson (2007)
Dual Degree Programs	Double Major or Dual Degree Programs
Exchange Programs	Minor or Certificate Programs
Internships abroad	Internships abroad
Extended Field Trips Abroad	International Projects
Mentored Travel	Study abroad and academic exchange
Conducting Research Abroad	Collaborative and global research projects
Project-based or service learning programs	Global teaming
	Service Learning Projects

Dual degree programs offer students the option to take an engineering degree and another in liberal arts or international studies, with credit load overlap designed into the degrees to the extent possible in order to reduce the overall time to around five years (rather than four). Often, though, there is little linkage between the degrees, and they can be seen as separate programs, as may minors or certificate programs where international studies or languages are studied

alongside an engineering major (Lohmann, Rollins Jr, & Hoey, 2006). Global teaming is a relatively new approach to engineering education and normally takes place in engineering design project courses. Global teaming creates student teams where team members are located at institutions in different geographic locations, working together towards the project objectives (Pienaar, Wu, & Adams, 2016). A study of global design teams that came from an international engineering class collaboratively developed and jointly offered by five leading global universities showed that the local teams significantly out-performed the global teams in terms of several measures: utilization of resources, experimentation/creativity, and evaluation of team functions (Liu, Dai, Morrison, & Lu, 2015). However, students in a globally distributed contest built into a software development course that is run by 12 universities located in 11 countries in South America, Europe, and Africa were surprised by how “normal” the engineering aspects are; the real challenges are in the communication and management of the global teams (Nordio et al., 2014). In almost every case, the appropriate use of technology is central to successful global teams but should not be restricted to communication tools; it should include tools to help the teams work together (Johri, 2010).

The National Science Board of the National Science Foundation reported in 2014 (this statistic was not included in the more recent 2016 report) that 24.9% of science and engineering papers published worldwide in 2012 were internationally co-authored and for science and engineering papers published in the United States in the same year, 34.7% were internationally co-authored. This was an increase from 1997 of 15.6% and 19.3%, respectively (National Science Board, 2014), which demonstrated the increased interest and direction from industry and funding bodies for researchers to conduct trans-national research projects. This context is creating opportunities in some universities for undergraduate engineering students to engage in

international research projects. Comparisons of international and domestic undergraduate research opportunities demonstrated that international opportunities significantly affected students' self-assessment on measures of intercultural competency skills and self-efficacy (Matherly, Phillips, & Chapman, 2015; Matherly, Phillips, & Kono, 2013). The University of Pittsburgh's International Research Experience for Students Program (IRES) focuses on sustainable engineering research, and over a twelve-week summer period, students spend eight weeks researching in the United States before traveling to their partner University of Campinas (UNICAMP) in Campinas, São Paulo, Brazil, for the final four weeks. Their initial results demonstrate that alongside the increased levels of global competency, their students have also progressed their research internships into fuller projects and translated their experiences into the rest of their program. Some have taken their research forward into graduate programs, etc. (Larimer, Tabone, Mehalik, & Needy, 2008).

International Experiential learning for engineering students

The Forum on Education Abroad defines a study abroad programs as: "In-classroom and out-of-classroom related activities that comprise a credit-bearing education abroad experience." Their standards further suggest a number of outcomes related to study abroad, namely, intercultural understanding, leadership skills, service orientation, maturity, and tolerance for ambiguity (The Forum of Education Abroad, 2015). Service learning is a teaching and learning model that supports community-based service with instruction and reflective practice to teach civic responsibility and support communities while delivering a rich learning experience to the students. In higher education, service learning can be curricular or cocurricular courses that include a community service element or alternative breaks if they have instructional and reflective components (Keen & Hall, 2009). Some, but not all, of these different options include

an experiential learning component; this is a different style of learning (and teaching) from the traditional engineering program, where teaching and learning is often decontextualized. For Dewey (1939) and Kolb (1984), experiential learning occurs when knowledge is created through experience, and, given the vocational nature of engineering (Beard & Wilson, 2013, p. 17) and the international travel inherent in many of these options, experiential learning is an essential aspect that supports the development of many of the professional skills and constructs outlined in Table 27. Experiential learning opportunities should engage the students in reflection, critical analysis, and synthesis during which there should be opportunities for students to take the initiative, make decisions, and be accountable for the results. It should provide opportunities for students to engage intellectually, creatively, emotionally, socially, or physically in the experience (Kyle et al., 2017) as this allows students to go through the different stages of observation and reflection, formation of abstract concepts and generalizations, testing of implication of concepts, and real, applied experience (Kolb, 1984). Yamazaki and Kayes (2004) further developed Kolb's (1984) model to develop a taxonomy of skills necessary for the cross-cultural adaption of learning and to account for the influence of culture. Through their model, they added twelve skills in four thematic areas tied to stages of the experiential learning model which demonstrate when these skills are most relevant. This study adapted Yamazaki's (2004) experiential learning model, as shown in Figure 166, to add the contextual effect on learning (Kayes, 2002) by including the subconstructs from the Global Preparedness model developed by Ragusa (2011, 2014). While the model includes informational and analytical skills and technical competencies, these are not the focus of this article. This study was designed to focus on the action and interpersonal skills and global and professional competencies in the context of the engineering global preparedness model. The investigation focused on the specific programs available to

engineering students at the mid-sized, western U.S. university to understand the comparative effect of these programs, through the lens of the global preparedness model outlined in Figure 16.

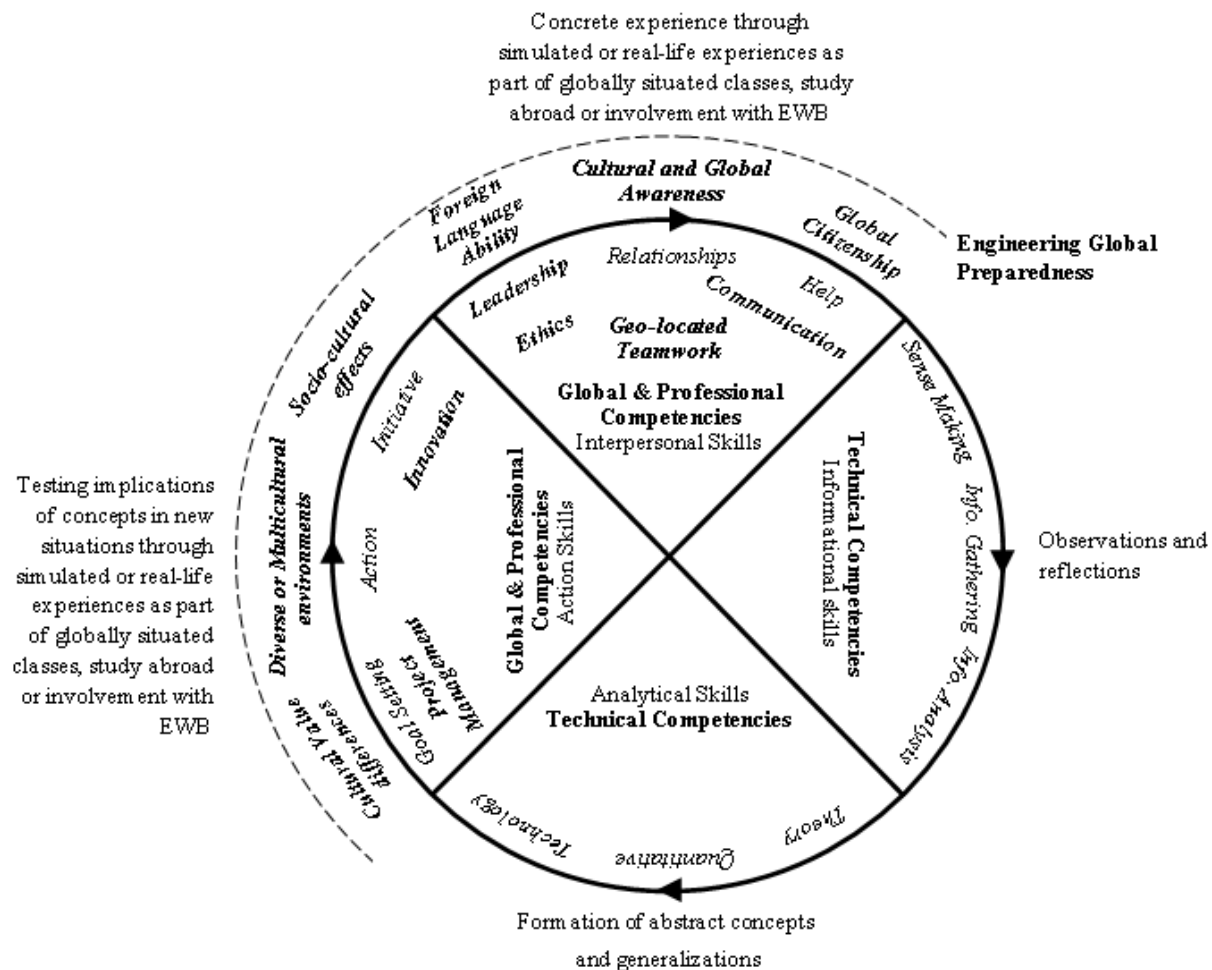


Figure 166. Engineering Global Preparedness Conceptual Framework. Adapted from *An experiential approach to cross-cultural learning: A review and integration of competencies for successful expatriate adaptation*, Y. Yamazaki & D.C. Kayes, 2004, *Academy of Management Learning & Education*, 4(3). Copyright 2004 by the Academy of Management

International experiential learning aligns with students interests

Vygotsky's (1978) social learning theory suggests that an individual's learning is centered in their own social and historical position and the social learning they have from that background; and this finding has been accounted for in this research through the use of a demographic questionnaire to understand students' background in terms of gender, parental

college experience, nationality, international experience, age, and other differences. These demographics effect the formation of individuals identities, which in turn influences why students choose to study engineering, study abroad, or choose to join the university's EWB chapter. Eccles (1983) expectancy-value theory provides a further explanation to help understand engineering as a life choice, based on two main constructs. The first construct of Eccles (1983) theory is a psychological construct built on personal competence-beliefs, goals, values, and interests. Aligning this the second construct, a socialization construct emphasizes the social, contextual, and cultural influences on an individual's development of self—through beliefs, interests, goals, and values (Wang & Degol, 2013). This can be represented within engineering as shown in Figure 177, highlighting the effect of the psychological construct; career interests, college experience and intellectual aptitude and ability factors. The socialization construct is also outlined, in the sociocultural and contextual factors that support and lead to many of the areas of the psychosocial construct.

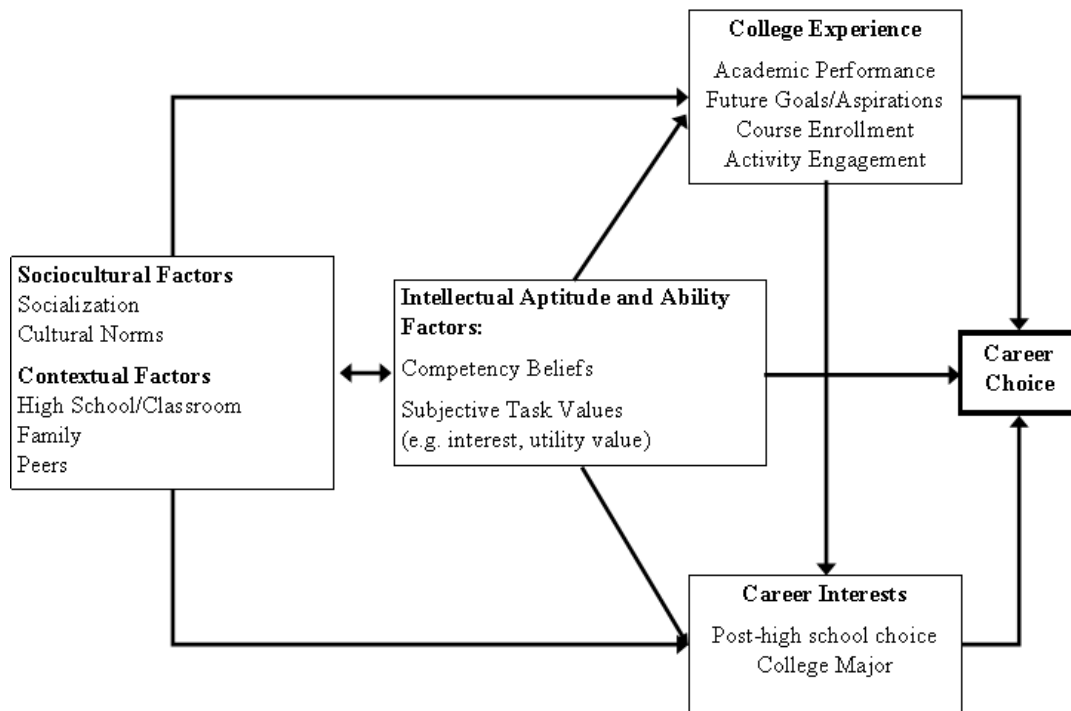


Figure 177. Theoretical Model of Career Choices based on expectancy-value theory. Reprinted from *Motivational pathways to STEM career choices: Using expectancy-value perspective to understand individual and gender differences in STEM fields*, M. Wang & J. Degol, 2013, *Developmental Review*, 33(4). Copyright 2013 by Elsevier

Understanding and acknowledging the effect of students' identities, their motivations, and how this has formed their interest in engineering, their engineering identity, study abroad, or joining EWB is fundamental to explaining some of the differences described by the students.

Research Question

Given the increased access engineering students have to international experiential learning opportunities, either on campus or through traveling abroad and the value these programs and classes have to some students engineering identity and motivation to study engineering, this study investigates;

- Comparatively, how do engineering students at a mid-sized, western U.S. university reflect on the effect of different domestic and international, curricular and cocurricular classes and programs on their engineering global preparedness?

Methods

Setting.

At the mid-sized, western U.S. university, there was the opportunity to compare three different curricular and cocurricular study abroad and volunteer abroad programs related to engineering to understand the value of these three different opportunities to engineering undergraduate students' global preparedness. It is important to be able to evaluate and compare different programs regarding their international factors, to both classify and understand the programs. The three programs are outlined below, classified utilizing the framework developed at the National Summit Meeting on the Globalization of Engineering Education (Grandin & Hirleman, 2009). The College of Engineering also offers a five-year dual-degree international engineering program, through which students gain a bachelor's degree in engineering science and international studies, with a concentration in one of four geographic areas: Asia, Europe, Latin America, or the Middle East/North Africa. One student from this program was interviewed as part of this study.

Engineering students who have studied abroad for a semester or more.

The mid-sized, western U.S. university has a Study Abroad department dedicated to supporting both short- and long-term study abroad opportunities for students and collects data on students who have been or are in study abroad programs and exchanges. The study abroad data in Table 29 showed that by the end of the summer 2017 semester, 37 current (not graduated before end of fall semester 2017) engineering undergraduate students that had studied abroad in either short- or long-term programs during their undergraduate degree were still enrolled as students at the mid-sized, western U.S. university. It should be noted that not all of these

students undertook an engineering-related study abroad; some undertook language or social science-based study abroad or exchange opportunities.

Table 29

Demographics of engineering undergraduates who have studied abroad

Engineering Major	No. of Male Students who had studied abroad (short-term—less than a month)	No. of Female Students who had studied abroad (short-term—less than a month)	No. of Male Students who had studied abroad (long-term—a semester or more)	No. of Female Students who had studied abroad (long-term—a semester or more)
Civil & Environmental	3	8	4	1
Mechanical	7	4	7	5
Chemical and Biological	0	4	2	1
Biomedical	0	3	3	4
Electrical and Computing	3	1	0	0
Engineering Science	0	4	0	1
Subtotals	13	24	16	12

Students for this group were recruited by email from the 28 students who had studied abroad for more extended periods of time (a semester or more) utilizing an IRB approved recruitment email (see Appendix E), starting with those who had studied abroad most recently, until ten students were recruited. This group all selected programs either taught in English or chose to study foreign language courses (such as Spanish and French); the programs were not all engineering specific, with half of the students choosing to study their required non-engineering electives while abroad. These programs have no formal, structured language or cultural preparation and have differing levels of cultural and language immersion. These programs have university-level institutional support but, as is reported by the students, low levels of institutional

support within the engineering college, given the challenges presented to students to align studying abroad with their engineering degree programs.

Engineering students who have undertaken a short-term (3 weeks) global engineering or sustainable building three-credit study abroad program in China and Costa Rica.

For two years, the instructor who teaches both the first-year design civil engineering design classes included in this study also led a three week “Grand Challenges in Engineering” program, based on the “Grand Challenges in Engineering” (National Academy of Engineering, 2008) and hosted at a university in China. Over the two years the program ran—2014 and 2016—eighteen engineering students from first through the fourth year and different engineering disciplines undertook this course, which was a mix of cultural, language, and contextualized engineering classes, all taught by instructors from the Hunan University. This course was the only available study abroad that could be utilized by some engineering students as a technical engineering elective as part of their degree program. Engineering students who are minoring in Construction Management also have the option of taking the Sustainable Buildings: Introduction to Sustainable Design and Construction in Costa Rica three-week program and counting it as credit toward that minor. As part of this faculty-led program, students travel to Costa Rica to work with local students at EARTH University (Carlos Rafael & Marisol, 2017) in San Jose, Costa Rica, and members of the local community to learn the principles of sustainable design and construction. This program is supported and taught by faculty from the Department of Construction Management at the mid-sized, western U.S. university, and most of the students are from that department, with one or two civil engineering, interior design, and landscape architecture students taking the course over the last few years. Every engineering student who had undertaken these two programs was that was still enrolled at the university was sent an IRB

approved recruitment email (see Appendix E), and all students contacted agreed to be interviewed as part of this study. These two, curricular study abroad programs have both university- and instructor-level institutional support, with differing levels of college level support. The programs both require some level of cultural immersion and while both are taught in English, the Sustainable Buildings program hosts students with Spanish-speaking families and requires a level of interaction with the local community.

Engineers Without Borders USA chapter students.

The final group was drawn from the student membership of the Engineers Without Borders (EWB) USA student chapter at the mid-sized, western U.S. university. EWB-USA is an NGO based in Denver, Colorado, which “supports community-driven development programs worldwide by collaborating with local partners to design and implement sustainable engineering projects, while creating transformative experiences and responsible leaders.” (Engineers Without Borders USA, 2017) The NGO has 288 student and professional chapters across the United States (Engineers Without Borders USA, 2015) with a student chapter at the mid-sized, western U.S. university in which this study is situated. Students in this group were recruited (see Appendix E) in person through the author’s attendance at chapter meetings and through the IRB-approved recruitment script. This student-program group is cocurricular, with minimal institutional support; there is little formal requirement for language or cultural preparation, as this is dependent on the decisions of the chapter leadership team. The students who travel to work with their community partners tend to spend two or three weeks working and living with the community.

Participants.

This study took place at the College of Engineering at the mid-sized, western U.S. university between January 2017 and February 2018. All the participants were engineering undergraduate students in the College of Engineering, and the interviews took place in a conference room within the college building or the student center. The number of students, the data collection method, and the period for the different study groups are shown in Table 30.

Table 30

Different student-program groups studied based on which programs they experienced

Learning Opportunity	Number of Students	Data Collection Period
Engineering students who studied engineering abroad with a university study-abroad for a semester or more	10	Spring 2017-Spring 2018
Engineering students who took a short-term (3 weeks) three-credit study abroad program in Costa Rica or China	8	Spring 2017-Spring 2018
Engineers Without Borders USA chapter students	10	Fall 2017/Spring 2018

Of the twenty-eight students interviewed, fifteen were female, and thirteen were male; the students came from six different engineering programs as denoted in Table 31.

Table 31

Program demographics of students interviewed

Engineering Program	Number of students
Civil Engineering	12
Mechanical Engineering	6
Environmental Engineering	3
Electrical Engineering	1
Chemical Engineering	5
Engineering Science	1

Materials.

Ragusa's (2011) definition of global preparedness is a challenging concept to understand and to measure, as it is built of these four latent constructs—that is, unobservable factors or characteristics that are recognized as essential aspects of learning but are challenging to measure independently (Wilson, 2005). Due to the small numbers available to participate in each group, quantitative data collection utilizing the Engineering Global Preparedness Index developed by Ragusa (2011, 2014) would not be appropriate and so interviews were used to provide a greater depth of information and a more holistic overview than is possible through quantitative instruments (Knupfer & McLellan, 1996; Kvale, 2009). Interviews also provide the opportunity for the researcher to explore and clarify responses from the interviewee along with exploring emerging themes, which is not possible through investigating artifacts such as examinations and portfolios (Alshenqeeti, 2014).

Demographic questionnaire.

All participants in the study completed a demographic survey, which was adapted from the Engineering Global Preparedness Index (EGPI) developed by Ragusa (2011, 2014). This survey asks the participants for their age, gender, racial/ethnic background, generational citizenship, and current engineering major as well as if they have lived, done community service, or studied abroad. One question was added to ask participants if they have been or are involved with Engineers Without Borders USA or another international engineering service organization. This item was added to check for students who may appear in more than one of the groups. For full details of the demographic questionnaire, please see Appendix A.

Semi-structured individual interviews.

The interview protocol used in this study was developed following the format suggested by Jacob and Furgerson (2012) utilizing a question set created as part of a National Science Foundation (NSF) Research in Engineering Education (REE) project undertaken at three collaborating institutions in the United States (Streiner et al., 2015). This study used the EGPI instrument along with the Global Perspective Inventory (Engberg, 2013; Engberg & Fox, 2011) as part of their protocol.

The semi-structured interviews utilized the following questions from the Streiner et al. (2015) study:

- Why did you choose to study engineering (and to go to <country or class/program>)?
- Did the <class or program> change the way you think about engineering?
- Did this <class or program> affect your thinking about the cultural relevance of engineering?

One additional question was added to the protocol to match the aims of this study:

- Do you think your <class or program> has had any effect (positive or negative) on your non-technical engineering skills, such as teamwork, communication, leadership, and global and cultural adaptability?

All the questions were shared by email with the interview participants before their interviews, for full details of the interview protocol please see Appendix H.

Procedures

Study abroad interview procedure.

This interview protocol was developed following the guidance provided by Jacob and Furgerson (2012). Potential participants were identified using email lists provided by the

instructor or the university's study abroad office. Students were contacted individually, utilizing the IRB approved email recruitment template (see Appendix E—Email Recruitment Template for Interviews); if they responded with interest, the interview consent form (see Appendix F—IRB Approved Consent Forms) and interview questions were shared with the potential interviewee. A date and time were set, and a quiet conference room in the College of Engineering or the student center was booked, depending on which was most convenient for the participant.

On the arranged date, after the participant had reviewed and signed the consent form, the interview started with basic background questions. The participant was asked to complete the demographic questionnaire (see Appendix A) and was asked to confirm that audio recording was acceptable or if they would prefer written notes to be taken. During the interview, the research questions were utilized as starting points, with follow-up questions dependent on the direction of the conversation.

EWB-USA Student Chapter interview procedure.

The interview procedure for the EWB-USA student chapter members is similar to the interview protocol for Study Abroad participants. The recruitment procedure, however, started with the author attending a chapter meeting and reading the IRB approved recruitment script for the EWB chapter members (see Appendix E—Verbal Recruitment Script for use in Recruitment of EWB-USA Chapter Members). From this, an email list was generated and the interview procedure described earlier was followed.

Transcription and Analysis.

Interview data were transcribed, and although interviewee transcript reviews do not tend to add to the accuracy of the transcript but can lead to the loss of data through the interviewee

choosing to remove data (Hagens, Dobrow, & Chafe, 2009), member checking was utilized to check for credibility as part of the validity of the data. The interviews were transcribed in Nvivo and analyzed using the Qualitative Content Analysis (QCA) framework (Roberts, 2000), being coded using the sub-constructs from the EGPI instrument and the professional skills identified and through open coding to allow themes to emerge from the data; this enabled the qualitative data to act as a support to themes generated through the interviews and those proposed by the EGPI subscales. Once the codebook was established (Appendix G), all interviews were re-coded using this standard set of codes to ensure consistency across all interviews and an interrater reliability analysis using the Kappa statistic was performed to determine consistency between the two coders, one female, one male, both of whom were at the time of coding, doctoral students in education.

These themes, the codes, and data were used to describe student's reflections on the different programs and classes and to make comparisons of their effect on student's global preparedness based on the demographic similarities and differences as described previously. This is an iterative process, visualized in Figure 18, in which meaning is derived from many iterations of the analysis (Bazeley, 2013).

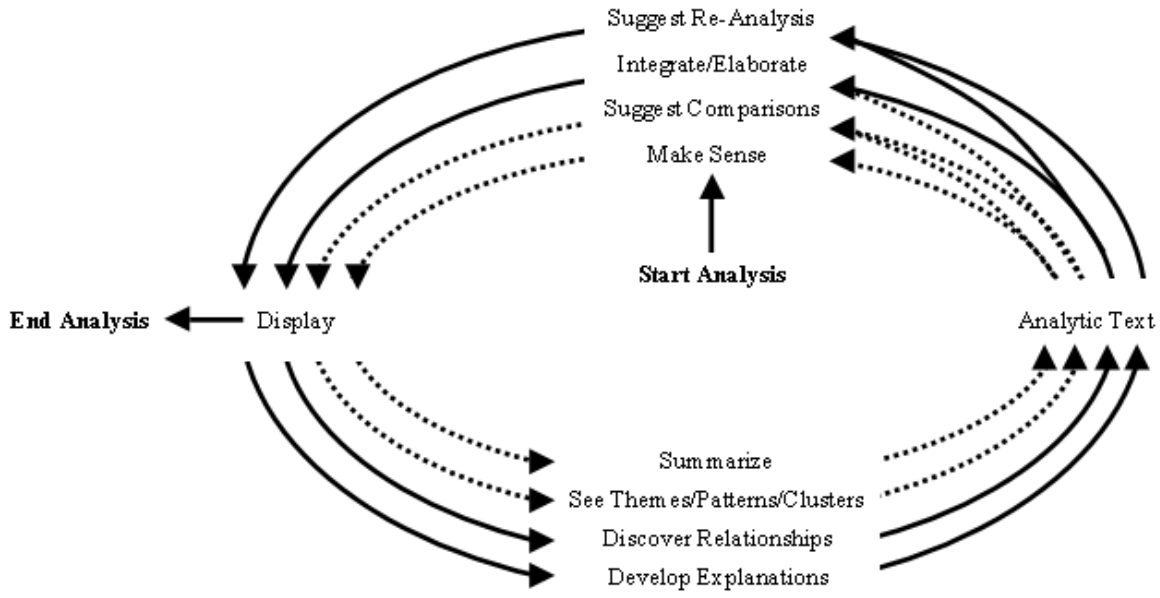


Figure 18. Interactions between display and analytic text. Adapted from *Qualitative data analysis: an expanded sourcebook*, M.B. Miles, 1994, Thousand Oaks, CA. Sage Publications. Copyright 1994 by Sage Publications

The themes/patterns/clusters and relationships derived from the analysis of text are shown in Table 32, which were utilized to code and recode the text before the final analysis and development of the results. In addition to the global and professional competency constructs which were coded as part of the study design, two additional constructs emerged from the data; effects and differences, and student career and study choices, which are related to Vygotsky's (1978) social learning and Eccles (1983) expectancy-value theories and the psychological and socialization constructs that effect engineering students identities and career choices.

Table 32

Coding developed from analysis of text

Constructs	Themes/Patterns/Clusters
Global competencies	Community Service, working with local communities Foreign Languages, language barriers Reflections on cultural relevance of engineering Global and cultural awareness Global, international, transnational Working with diverse teams, communities Global Citizenship
Professional competencies	Teamwork Communication Ethics Leadership Innovation and Entrepreneurship Project Management Other non-technical skills
Effects and differences	How EWB, study abroad or class has affected how you think about engineering Has international travel affected them, differences they noticed Different styles of teaching and learning Reflections on gender in engineering
Student career and study choices	Why students chose to study engineering Why students chose to study abroad Why students chose to join EWB Students future career or study plans

Results & Discussion

After coding, in addition to the global and professional competencies, more coding constructs emerged from the data; these focused on why students had chosen to study engineering, study abroad, and join the university's EWB chapter. Students also reflected on the relevance of culture to engineering, how international travel had affected them and how their experiences affected their future career or study plans. With these additional codes, both coders

recoded the data, resulting in an intercoder reliability kappa score of 0.64, which demonstrates substantial agreement between coders (Landis & Koch, 1977).

Experiential learning effects on professional and global competencies.

Within this study there are three groups that contain different deliberate experiences, three dimensions of which are outlined in Table 33. This only includes experiences provided by the different programs and does not account for the equally important, and different, experience the students bring and their effect on the experiential learning context (Vygotsky & Cole, 1978).

Table 33

Different experiences provided for students in each of the three study groups

	Study Abroad for a semester or more	Short-term study abroad	EWB Chapter members
International Travel	Yes, students interviewed traveled to the United Kingdom, Australia, Denmark, Netherlands, Italy, Costa Rica and Spain	Yes, Costa Rica or China	Some students have traveled to El Salvador (some have also traveled to the Pine Ridge Reservation in the Sioux Nation)
Intentional global and/or cultural awareness education	None	Yes, both study abroad programs include reflective exercises on culture, and both include formal or informal cultural awareness education	Optional training is provided by EWB-USA online. The chapter has organized training in the past with a local NGO
Team-based project	Engineering courses at a university abroad may include a team-based project. These projects are either in local context or decontextualized	Costa Rica—Yes, students work on a construction management team project with other study abroad students and local, Costa Rican students China—No	Yes, all students had worked on one of two projects, with communities in La Criba, El Salvador and Pine Ridge Reservation, South Dakota

The effects of these different experiences on the students' global preparedness is very clear from the students' reflections on the cultural relevance and differences in engineering. Engineering students that had a team-based project either in El Salvador with EWB or in Costa Rica on study abroad can generalize ideas about differences in culture and how they affect engineering and their individual perspective and ideas about engineering:

I think kind of, what we were talking about a little earlier that um, there's different decisions that get made based on culture and to have been out and seen you know, what different cultures look like and that kind of thing it gives you, even if you haven't experienced you know, the culture that you may be dealing with, it can help you to I guess be open to maybe, you know, if you don't understand some decision or some aspect of what you are working on it can easily be a cultural thing and it helps to have that experience and it helps to have an open mind about that for sure. (*EWB, Mechanical, Male*)

The effects of culture on engineering decisions was made clearer for students by the experiential learning, such as the students who constructed buildings using traditional techniques and materials in Costa Rica:

There was also, um, we worked on a smaller project where we actually physically built this little house hut kinda thing, out of, um, it's called, Bahareque, with mud and straw and I think lime and you can build mud houses. Um, that was really interesting for me too because a lot of their infrastructure there isn't necessarily super well-built but it doesn't really need to be because that is sustainable enough for them, they don't really have any climatic hazards like we do up in the U.S. where we need really really well built things so that, that, also opened my eyes a little bit to, people can live in a mud house and

that, it's not that that's a bad thing, cause often times we'll be like "oh, they live in a mud house, that's so poor" but it's like no, they've got what they need. (*Short-term Study Abroad, Civil, Female*)

Students who did not have this team-based experience working with local community members, on the other hand, have a more individualistic response to cultural differences in engineering, focusing on how it might affect them as an individual, or specific technological differences that were important to them. Comparing how individual career paths were different in their study abroad country and at home was a common theme:

First of all, I got a lot more of an appreciation for the U.S. in engineering, I don't know, maybe, South Australia specifically was having a really hard time with getting jobs for engineers kinda for engineers right outta school so a lot of my, people that I worked with were getting ready to graduate and were really concerned that their degree wasn't going to be worth anything. Um, which is very different to here because here when you graduate with an engineering degree you have a lot of different options in the U.S. and so I think I got a lot more of an appreciation of that. (*Semester or longer Study Abroad, Mechanical, Female*)

Students commented on how working abroad or with foreign companies or clients would affect their career, or how working with engineers who had been educated in other countries would become part of their career:

It's interesting to see how they think about it because in today's world it's likely, it's almost certain that I will be working with an engineer from China or with a Chinese company or with someone from some other culture just because the World is getting smaller, more and more people and companies are interacting so I think a big part was

that whole thought of trying to see things from other people's point of view and to see everyone tries to solve the problem differently. I mean, it's kind of great to see that and to see that your one solution isn't the best solution, what works for you, what works for me in [city] might not work for someone in Beijing or Changsha or anywhere else.

(Short-term Study Abroad, Mechanical, Male)

Another student who studied abroad reflected on the parts of their experience that directly related to their individual, existing interests and the differences to their experience in the United States:

As a class we all went on field trips, we went to different cities around the Netherlands too and um, what interests me the most, I'm really into cars and stuff and seeing all the different brands of cars and um, the electric car thing there was pretty interesting, they have like charging stations everywhere and um, a lot of people drive Teslas and there is like, there is like these weird mini smart cars that are electric that people are just like driving around in them and they're in the bike lane or the center of the street, like, they seem pretty, they seem like they're having fun driving those around. *(Semester or longer Study Abroad, Electrical, Male)*

These student reflections demonstrate that all engineering students appear to gain through international experiences, an understanding of how engineering is different around the world. However, students who undertook a project while abroad appear to be able to articulate a deeper understanding of the cultural aspects and impacts of global preparedness, while students who did not undertake a project, demonstrate reflections based on the differences they noticed from their own culture or technologies they are familiar with. This aligns with Yamazaki and Kayes (2004)

modification of Kolb (1984) experiential learning model, in that students able to observe and reflect on the new context they find themselves in and may be able to form abstract concepts and generalizations about that context and its effects on them, such as students reflecting on differences on technologies like electric cars, or how working for an international company or with international colleagues may affect them. However, to move beyond this level of understanding, engineering students need the opportunity to test out their conceptualizations and refine and deepen their understanding through application in the form of an engineering project, which leads to a deeper understanding of how culture and engineering design interact, as was demonstrated by students reflecting on international project experiences. It is also important to recognize the effects of instructor support on the goal of developing global preparedness. There are two groups in this study, the EWB chapter students and students studying abroad for a semester or more who do not have explicit instructor support to develop global preparedness. Students within the EWB chapter have opted into the organization based on their interests and goals and so, generally, are focused on engineering in the global development context. Engineering students studying abroad for a semester or more at a university abroad can, however, find that their classes at that university are de-contextualized, technical classes and may not support them in gaining any global preparedness, other than the learnings they may choose to gain themselves through living in a different country:

I did take a class where, um, we were focusing on, just kinda Australia specific things but that was more um, we were doing a design for a drone launcher and the drone was working on almond farms so it was very specific to South Australia because there is a lot of almond farms there apparently, but it wasn't necessarily focusing on the whole, like, how it affects it globally or things like that. Um, we probably got a little bit more global

context just in general with the people that we were working with cause kinda like I mentioned before with Australia, you know you get a lot of students coming from Asia and a lot of students from the Middle East and so that was probably a little more of culture I got exposed to just from interacting with other people but I don't think the courses themselves were really focused on it a whole lot. (*Semester or longer Study Abroad, Mechanical, Female*)

An aspect of experiential learning often assumed to be part of the student's personal environment, is their lived experience and the effect this has on their learning. Understanding of students lived experience in engineering education is predominantly limited to understanding their motivations to study engineering (Cass, Hazari, Sadler, & Sonnert, 2011; Dunsmore, Turns, & Yellin, 2011; Orr, Hazari, Sadler, & Sonnert, 2009), and their experience on campus while studying engineering (Kirn, Godwin, Cass, Ross, & Huff, 2017). In this study, it is important to recognize the previous international experience of the students interviewed as many of the students had previous international experience, had been born outside the United States or were also, or had been, involved in the EWB student chapter at the university as can be seen in Table 34.

Table 34

International related lived experiences of students participating in this study

	Number of students			
	Total Interviewed	Not born in the U.S.	Had previously lived in, done community service or studied in a foreign county	Involvement in EWB Student Chapter
Learning Opportunity				
Engineering students who studied engineering abroad with a university abroad for a semester or more	10	0	5	1
Engineering students who took a short-term (3 weeks) three-credit study abroad program in Costa Rica or China	8	1	3	3
Engineers Without Borders USA chapter students	10	1	7	10

Many studies focus on travel (Prater, Riley, Garner, & Spies, 2015), and study abroad as transformational experiences for students (Stephenson, 1999; Wright & Larsen, 2012), however there is little reflection in these studies on the effect of students own previous lived experience and how they brought these experiences to their study abroad or EWB chapter involvement. This study recognizes through qualitative comparison of the number of times coded items were reflected on by students in the different groups, the suggestion that lived experience does affect their reflection on their learning opportunity, however, the small size of the groups within this study do not allow for any conclusions to be drawn.

Students' development of professional competency.

The Engineers Without Borders USA student chapter at the university during this study had three community projects at various stages (one of which was at a feasibility stage and was

not suitable for inclusion in this study). Some students who were interviewed were involved in a long-term project in El Salvador, which has been based on creating a water treatment and distribution system since 2008. This project is nearing completion, so the chapter, community, and other stakeholders are discussing future collaborations. Other students are involved in a newer, more recent project, working with a Native American tribe to build a community center. This project has been in the planning stages for the last two years, and the chapter and community broke ground on the construction in the fall of 2017. The students involved in the university's EWB chapter reflected on professional competencies during the interviews and recognized the importance of EWB to their development of professional competencies:

I think most of my professional skills have come through work experiences and Engineers Without Borders and the other student orgs that I'm a part of, like, play a role I guess. (*EWB, Mechanical, Female*)

Given the project-focused nature of EWB chapter work, teamwork and project management competencies were a particular focus for EWB chapter student members.

As far as EWB goes, I definitely, that's been the best um, for me in terms of like, working in a team on a project, I haven't gotten any experience elsewhere that's even close to what I've gotten from EWB. (*EWB, Mechanical, Male*)

Students involved in EWB can clearly demonstrate their professional competencies, how they develop and practice these through their involvement in the chapter and in the three projects, and how these professional competencies will relate to their future career, in particular the importance of learning how to work as a team in a "real" situation, as compared to team projects in engineering classes:

There's a couple, a couple project classes in the mechanical curriculum and um, I don't know, one of them, they're both good experiences of working you know, in a team on a project but the projects don't seem, they don't seem especially uh, um, I guess, accurate to what you would do in the real world[...] whereas in EWB we're actually doing things for, for you know, real people so that's a much better, I feel like it's been a much more accurate experience in that kind of teamwork and what delivering on a project looks like.

(EWB, Mechanical, Male)

Students remarked on how decontextualized problems are in engineering classes and how their involvement in EWB has developed understanding of how engineering happens in practice:

In classes you learn about the very specific, isolated problem, how do you solve that and in EWB is a very different sort of poorly defined problem so you have to narrow down what you can, uh, solve and what you need to just, figure out um, as you go, so. I've definitely learned a lot um, I never really knew prior to EWB what uh, engineers really did out in the field. *(EWB, Chemical, Male)*

EWB student projects also help students understand teamwork within multi-disciplinary teams, working with students from different disciplinary backgrounds and experience levels on real projects, and how this relates to their future careers:

I think on the water project [El Salvador] it's definitely different from my classes because now you're actually applying the things you've learned, um, and you're also working with people who don't necessarily have the same level of knowledge that you have, [...] cause some people are freshmen, some people are seniors so some people have already learned more than others um, and so, that certainly helps you with teamwork a lot more which I think is really helpful in your career, um, teamwork and making sure everybody

is working together, I think I've learned a lot of that during my time with EWB, I think that's been really wonderful and I think it's going to be really helpful during my time in industry. (*EWB, Civil, Male*)

Leadership is also an area highlighted by EWB chapter students as an area in which they feel they can choose to gain experience through leading EWB projects, or design teams within the overall project:

I mean my team that I am the team lead for is very small [...] but still we do have, you know, a list of things that the project needs from us and um, and we have to, um, kind of you know make sure that we're moving and delivering on those things so, I definitely have been learning kind of, how to, how to keep you know a team on track and keep ah, you know, ourselves organized and making progress on things that we need to get done. (*EWB, Mechanical, Male*)

Students also feel that their leadership experience is vital to their future employers particularly as they compete in the job market for internships, graduate degree programs, and graduate engineering jobs:

It definitely is on my resume, and um, because I am listed as the ex-vice president and project lead they, they see that leadership and they really, they really enjoy that, and they're always really interested. (*EWB, Mechanical, Female*)

It should be noted that only students studying abroad in Costa Rica (two students in this study) were asked to partake in a team-based project as part of their experience, while some, but not all, of the students studying abroad had a team project in one or more of their classes.

The only area of professional competence reflected on similarly by the study abroad students and the EWB student chapter members was communication, although the nuances were

different, and the different groups tended to have different learning about communication from their experiences. It should also be noted that the overall sample size in this study is relatively small. EWB students reflect on the importance of communications as part of engineering:

As project lead certainly, um, I've had to learn to present to a more general audience because incoming students, people who like when I started are intimidated by the prospect of being on the design team or just EWB as a whole [...] that's very different to what we do in the classes when we presenting to other students or colleagues who, they're going through the exact same assignment. (*EWB, Chemical, Male*)

Study abroad students, on the other hand reflect on the importance of interpersonal communications to their effectiveness as individuals, not necessarily as engineers:

China really challenged me communication-wise, it really made me think of how, when you have so many ideas, you really want to share with someone but there is a huge barrier with language, and I never thought that, so just that was really mind-blowing, the whole experience psychologically and sociologically, the whole thing was really interesting, not just engineering wise. (*Short-Term Study Abroad, Chemical, Female*)

Study abroad students also reflected on the value of travel to developing communication ability and how this supports their future career prospects;

I think I'm just more confident now that I like, studied abroad, um. I've been really trying to get that internship, and it's all about communication and being comfortable with talking to employers [...] I just think having like experiences to talk about and my study abroad experience, talking to employers they love that. (*Semester or longer Study Abroad, Civil, Female*)

Gender differences—engineering identity development through global preparedness.

The widely held public perception of engineering (as with most STEM subjects) is of a well-paid career focused on working with inorganic materials in isolation and that engineering careers provide little opportunity to work with people and for the benefit of people (Diekman, Brown, Johnston, & Clark, 2010; Diekman, Clark, Johnston, Brown, & Steinberg, 2011). These perceptions align with two fundamental concepts, firstly *agency*, as an independent and self-promoting concept, and *communication*, which focuses on building and maintaining relationships while working in the service of others (Stout, Grunberg, & Ito, 2016). Theories developed from research in societal definitions of gender roles demonstrate that men have traditionally held roles that value power and leadership and tend toward careers that allow for high levels of agency. Due to the traditional caregiver roles society assigns to women, roles that contain elevated levels of communication tend to be more appealing to women. Due to the societal pressures indicated by role congruity theory (Eagly & Karau, 2002), individuals tend to feel more comfortable and confident when they take on roles that have cultural and societal approval, which may partially explain why male students are more attracted to engineering as a career than are female students. The Institute of Mechanical Engineering in the United Kingdom describes this difference between agency and communication as the difference between describing engineering in nouns and in verbs which has driven them to re-market engineering (particularly at a high school level) in terms of verbs to focus on what engineers do rather than the products they create (Institution of Mechanical Engineers, 2016). It is significant that when students in this study were asked about their reasons for choosing to study engineering, male students talk about interacting with technologies in childhood—“things with big engines, planes trains and automobiles” (Semester

or longer Study Abroad, Mechanical, Male)—and “a curiosity for how things work” (Semester or longer Study Abroad, Environmental, Male) and that they were excited to study engineering due to it being perceived by their peers and family as a challenge, aligning with the idea of agency. All the students interviewed mentioned enjoying mathematics, physics, or chemistry in high school and seeing engineering as a natural career path; however, the female students talk in subtly different ways about challenges related to how engineering communicates itself and impacts people and communities:

The problem-solving aspect is what drew me to engineering but it’s also the real-world applications of it, like that’s when you, when you solve a problem and you see actual results, you know you see it going and doing something good, or you see it improving something or helping somebody out. (*Semester or longer Study Abroad, Mechanical, Female*)

Female Students shared that they chose to study engineering due to engineers ability to support and help people:

Definitely want to be a structures engineer but I have a minor in construction management [...], yeah, I love math and I knew I wanted to help people. (*Semester or longer Study Abroad, Civil, Female*)

Engineering was also seen as the career in which individuals can have the greatest impact on people in the future:

I feel like I can make the biggest impact on the most people by pursuing a degree in engineering. (*EWB, Mechanical, Female*)

Female students from all three programs talked about community service as either something they had done or wanted to do or that was an important part of engineering; the only

male students to mention community service were those in the university's EWB chapter. Consequentially, students in this study who identified as female were also twice as likely to reflect on language barriers as an issue in engineering than students who identified as male, alluding to the relative value they see in communication in engineering.

The results from this study demonstrate that there is a definable difference between students' reflections on their learning from curricular and cocurricular engineering programs that include, or do not include, an experiential learning component in the form of an engineering project in the country they are studying or volunteering in. While all students seem to gain through observation an understanding of the difference in cultures and technologies in different countries, students that are involved in a project can deepen this learning, through understanding the role of culture in engineering design and how different cultures lead to different engineering design decisions. Furthermore, engineering students involved in experiential learning through a design project can demonstrate and substantiate their development of key professional and global competencies, such as leadership, communication, and global and cultural awareness. However, students who did not have a project as part of their international experience were not able to do demonstrate their development of these same key competencies. An aspect that emerged from this study is the importance of engineering student's own life experiences and reasons for studying engineering and taking part in curricular or cocurricular international programs. Demonstrated by the gendered differences in reflections on the importance of communication to engineering projects, these results highlight the role of students, and the importance of their own goals and experience as individuals in their development of global preparedness through these curricular and cocurricular programs.

Discussion

These results in many ways aligned with the engineering global preparedness conceptual framework, based on Yamazaki and Kayes (2004) modification of Kolb (1984) experiential learning model, presented in Figure 16. Students who had studied abroad but had not had an experiential learning opportunity in the form of an engineering project, demonstrated development in the technical competencies related to global engineering. In their own words, shared in the results section of this article, they demonstrated observing and reflecting on differences in culture and technology, and in some cases the formation of abstract concepts and generalizations they as individuals experienced between the engineering, technologies and culture they know, and the engineering, technologies and culture they observed in the countries they travelled to. Students who had had an engineering project in the country they travelled to, either through the EWB chapter projects or through study abroad programs, were able to demonstrate similar technical competency development. These students were also able to demonstrate development of the global and professional competencies embedded in the engineering global preparedness conceptual framework. While many of the individual items in the framework were not reflected on by any of the students, students who had undertaken a project were able to highlight their personal cultural and global awareness based in the concrete experience of their project, through reflecting on the impact of the differences in culture on their engineering design. Students were able to identify their personal development of professional competencies, such as leadership and communication, and demonstrate how the experiential learning of an engineering project in a foreign country had directly led to their competency development. Some of the difference can also be explained by the intentional reflective practices utilized by the instructors in two of the classes. Reflection is a fundamental part of experiential

learning, as it is a transformative process that allows the student to take the learning they have gained in what may be an unfamiliar context and culture, and translate it to expand or change their existing building body of knowledge and way of knowing (Turns, Sattler, Yasuhara, Borgford-Parnell, & Atman, 2014). Without this reflection section of the model in Figure 16, students may see their experience as separate from their studies (Eyler, Giles, & Schmeide, 1996) and it may have no impact on their global or professional competence. Both of the short-term study abroad programs in this study have intentional reflection practices designed into the program by the instructor, while the EWB Chapter students and students undertaking longer-term study abroad programs don't typically have any reflection requirements, although they may personally choose to reflect, or do so to some extent as part of project debriefs in the EWB student chapter. The effect of reflective practices on student's competency development wasn't part of the rationale for this study, but it is highlighted as a potential reason for some of the differences seen between the different programs.

The differences based on self-identified gender were not predicted in the development of the engineering global preparedness conceptual framework but are partially explained by the inclusion of the theoretical model of career choices based on expectancy-value theory model in Figure 17. This result is included as while it may not directly inform the engineering global preparedness conceptual framework, it does highlight that differences in students career interests, college experience, sociocultural and contextual factors, and intellectual aptitude and ability factors do influence the experiences that students bring to their involvement in study abroad programs and EWB, and that these differences in students experience and interest result in students having different outcomes from their time with EWB or study abroad. This study found that generally, it resulted in self-identifying female students reflecting on the importance of

language as a barrier to their understanding of the impact of engineering on different societies and cultures at an individual and community level, whereas self-identifying male students did not highlight this as an issue.

For most faculty, their global preparedness development in the academy is limited to international research collaborations, sabbaticals, exchange programs, attending international conferences and meetings (Egarievwe, 2015; Khedkar, 2012; Maillacheruvu & Al-Khafaji, 2014; McHale, 2006). While this method of engaging faculty in international research partnerships, or attending international meetings is seen by many institutions as a valid method of supporting faculty to gain global competency (Egarievwe, 2015), parallels should be drawn with the student experience outlined in this paper. While these experiences are a variation on experiential learning, in that faculty are able to observe, and sometimes test and practice in other global contexts, their experiences are, in the majority of situations, within the academy, visiting institutions in which they are linguistically able to communicate and teach or research. The effect of their experience may be similar to the students in this study who went on semester or longer study abroad programs in English speaking countries such as Australia, New Zealand or the United Kingdom. Without the support, cultural differences and design of an experiential program that is structured to engage faculty with different cultures, to help them to learn through doing and reflect on their learning – they may (similar to the students), gain very little. There are however, increasingly routes for faculty to support their own professional development in global and professional competency, from short term, experiential learning courses such as those offered by EWB Australia, who offer short (10-14 day) study tours for professional engineers and academics, to gain contextualized experience with their partners in developing countries. The association of Civil Engineering advocates for faculty to undertake professional internships,

or part time roles with engineering companies to gain professional experience and competence (Chou & Nykanen, 2009).

Unfortunately, the role of instructor's competence and how they gain this competence was not an area highlighted for investigation for this study and on review, students only reflected on instructors influence on their learning in general terms, rather than with reference to global and professional competencies. Faculty preparedness to teach or support the development of professional and global competence is an area that should be incorporated into future studies.

An issue that should be highlighted for this study, and many other studies that include study abroad programs and other international opportunities for engineering studies is the potential bias inherent in the students that typically undertake these experiences. As was outlined in the demographics of the students interviewed for this study, many had previous international travel experience or involvement in programs like EWB and it is typical of studies that focus on international experiences, to find that students often have multiple international experiences. These students are often part of a 'mobile global elite', students who have the financial resources, and often familial comfort with international travel, that allows them to partake in multiple international experiences (Vandrick, 2011). Often study abroad and service learning opportunities are exclusionary, due to cost and other factors, and participation levels from first generation students, PELL grant recipients and nonwhite students at predominately white institutions such as the institution investigated in this study are lower than other student groups (Stroud, 2010) and it may be seen as an unobtainable luxury (Ungar, 2016). Some of the solutions to this are financial, such as study abroad scholarships, or group fundraising, as is typically practiced by EWB student chapters to fund their project teams travel to partner communities. Another factor is connecting the study abroad experience to students own cultures,

communities, interests and academic studies (Barker, 2016; Ungar, 2016). Other options that instructors can employ to support student's global competency development are to bring global contexts and cultures into their teaching on campus. Programs such as the EWB Challenge, (Cook, Siller, & Johnson, 2016; Cutler, Borrego, & Loden, 2010; Mattiussi, 2013), Engineers for a Sustainable World academic programs (Dale et al., 2014; Hess, Aileen, & Dale, 2014) or Engineering World Health (Engineering World Health, 2016) programs are opportunities for instructors to leverage NGO experience to bring global contexts into their classrooms.

Conclusion and Research Recommendations

Global preparedness is increasingly important to engineering employers and is becoming an educational focus of engineering schools, through supporting students' development of global and professional competence and providing opportunities for engineering students to gain global experience. In this study, three opportunities for engineering students to gain global experience were compared through the student experience, focusing on their effect on students' global preparedness. While the positive effect of these programs was clear from students' reflection on their experiences studying abroad or as members of the university's EWB chapter, it was also clear that their learning and development of global competence was influenced by the experience provided to them through the three different programs and also by the experience they brought to the programs and goals they had as individuals.

All three of these programs are optional, and so the students that chose to take part in these programs and volunteered to be part of this research all had a pre-existing interest in international travel or engineering global development and community service. This study found that the experiences provided for the students differed greatly and this affected the students' learning and development of global preparedness. Students who had the opportunity to have a

concrete, international experience through the format of a team project working with local communities (through study abroad in Costa Rica or working with the EWB chapter communities) were able to demonstrate the different stages of the experiential learning model (Dewey, 1939; Kolb, 1984; Yamazaki & Kayes, 2004) and through this process of observation, reflection, conceptualization, experimentation, and implementation were able to deepen their global preparedness; by contrast, students who travelled abroad but did not have an experiential learning opportunity did not identify these stages. Similar results have been found with non-engineering students in other studies related to study abroad (Boateng & Thompson, 2013; Levine & Garland, 2015; Passarelli & Kolb, 2012); experiential learning allows students to move beyond surface-level, intellectualized conceptualizations and decisions to also be able to act on them in the real world (Bridges, 1993). These engineering projects also help support engineering efficacy through their development of professional competence, as has been found in other studies (Brake & Curry, 2016; Hirshfield, Chachra, & Finelli, 2015) and this study recommends the inclusion of experiential learning into all international learning opportunities for engineering students. This will strengthen the effect of the program on student's development of both professional and global competencies, and through reflection, will help students connect their experiences to their engineering studies. There are a number of engineering programs around the United States that are requiring study abroad or community service, either domestically or internationally as part of the degree program (Huff, Zoltowski, & Oakes, 2016; Moses, 2017; Zoltowski & Oakes, 2014), although given the inherent cost barriers to participation, this method is not a primary recommendation of this study. Engineering programs should however explore options that bring context and an understanding of different cultures into engineering programs on campus, to allow all engineering students the opportunity to develop global preparedness.

As the students clearly reflected, engineering and how it relates to people, communities, and context is a driver for many students to choose to study engineering, and they have reflected that experiential learning through engineering projects that are real and contextualized (rather than the academic, decontextualized projects they often encounter in engineering courses on campus) connects their studies to the reasons they chose to study engineering. Interestingly, students that studied abroad at partner institutions for a semester or two often found that if they did any team-based engineering projects in those countries as part of their study abroad program, they were also decontextualized and so the students did not tend to gain the same breadth or depth of global preparedness as the students who had an experiential learning opportunity. As such, the design of experiential learning opportunities such as design projects, is fundamental to their effect on students development of global preparedness. It is therefore recommended that international experiences are designed intentionally, with student's global preparation in mind, and are supported by instructors with the expertise to support students global and professional competency development.

As highlighted in the previous section, the effect of faculty on student's competence development was not captured in this study, and it, and the differing levels of preparedness of faculty to support student's competence development should be included into any future study, given the potential influence this may have on student's development. A second potential influencer that was not included in this study is, as part of program design, the importance of intentional reflective practices for students and a future study could investigate the impact of reflection on student's translation of their experiential learning to their development of professional and global competence.

This study is part of an emerging field of research tangentially related to Engineers Without Borders USA and the effect it has on engineering students (Litchfield & Javernick-Will, 2014; Litchfield, Javernick-Will, & Knight, 2014; Litchfield, Javernick-Will, & Maul, 2016; Walters, Greiner, O'Morrow, & Amadei, 2017) and adds a comparison to study abroad. There are opportunities to expand this research, such as comparing EWB student chapters at different universities in the United States or comparing with other engineering focused NGO's with student chapters such as Bridges for Prosperity or Engineers for a Sustainable World, to further understand the effect NGO student chapter involvement has on engineering students, their global preparedness, and future careers.

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Chapter 5 - Conclusions, Implications for Policy and Further Research

This study was designed to understand the professional and global competencies seen by key stakeholders in engineering education as fundamental to graduating and being prepared to practice engineering in the global economy. Then, using this understanding, to explore the perceptions and reflections of undergraduate engineering students on their experiences of different globally-orientated experiences during their studies at a midsized, western U.S. university. Undergraduate engineering students at the mid-sized, western U.S. university who had taken or were undertaking different curricular or cocurricular programs were surveyed and interviewed to understand the different effects these programs had on the students' perceptions of global preparedness and development of professional and global competencies. These programs demonstrated different stages of the conceptual framework model shown in Figure 16, with all of the programs that included a engineering project component allowing the students to test and practice their professional and global competencies, in either community projects in the study abroad or EWB chapter project location, or simulated through the EWB Challenge project. Interestingly, the majority of the long term study abroad programs did not include an experiential learning portion, such as an engineering design project, and very few of the programs studied included a mandated or structured reflection stage.

Summary of the Study and its Findings

The results of this study have been reported as three articles. The first, a systematic review of educational literature related to global preparedness and professional competencies with a focus on engineering, revealed the competencies and areas of global preparedness stakeholders in engineering education see as fundamental for students to learn before graduation. These findings aligned with the global and professional competencies found in the interpersonal

and action skill areas related to global and professional competencies of the engineering global preparedness conceptual framework for this study, based on modification of Kolb (1984) experiential learning model, presented in Figure 16. The framework developed for this study and Yamazaki and Kayes (2004) model is based on experiential learning theory, which integrates developmental learning with the knowledge, skills and abilities typically seen as part of competence (American Society for Engineering Education, 2018). Developmental learning is defined by Yamazaki and Kayes (2004) as a higher order of learning, that is developed over a longer term, so requires longer term experiences such as working on an engineering project in an international context. This definition of developmental learning as an aspect of the engineering global preparedness conceptual framework is important, as it reveals the importance of real world, experiential learning to engineering students' non-technical development areas such as professional and global competency.

The second article compared two first-year civil and environmental engineering classes and their effects on engineering global preparedness and professional competency development. One of these classes was an introductory class and allowed the students to explore different areas of engineering and their role as an engineer through guest lectures and discussion. The second class included a pseudo-experiential engineering project, in which the students worked in teams to support a community in Zambia with engineering designs for issues the community is facing. This comparison demonstrated the role of experiential learning, through group design projects, to students' development of engineering professional skills and the engineering efficacy subconstruct of global preparedness. As was expected based on the engineering global preparedness conceptual framework, and Yamazaki and Kayes (2004) definition of developmental learning, over the semester students described through interviews and reported

through surveys, developing competence and efficacy related to working in teams on an engineering project in a culture different to their own. While there was expected to be a difference between the two classes on all four subconstructs of global preparedness however, this comparison found no significant difference in the other three subconstructs of global preparedness: Engineering Ethics & Humanitarian Values, Engineering Global-centrism, and Engineering Community Connectedness. It is speculated that this may be due to the classes having the same instructor who shared in both classes, their philosophy and ethics around engineering in the US and globally, or that the project didn't give the students opportunity to develop competency in these three areas. However, it did demonstrate that the experiential learning component of the class, or EWB Challenge project, in isolation appeared to only effect the engineering efficacy subconstruct of global preparedness. Students in the Zambian design class did also, gain substantial global awareness of the engineering global preparedness conceptual framework (Figure 16) compared with their peers in the more domestically focused introductory class.

The third and final paper compared the reflections of students on their engineering global preparedness and professional and global competence development from three different groups; student who were part of the university's Engineers Without Borders chapter, students who had undertaken faculty-led study abroad programs and students who had taken semester or longer study abroad programs with partner universities across the world. These interviews again showed that the perceptions students had about these experiences and how they affected their global preparedness and professional competence was in part related to their international travel and cross-cultural learning as part of these programs, but was also related to the developmental aspect of experiential learning. Students who undertook faculty-led programs that included a

team design project component working with local communities or those who have traveled to the EWB chapter's partner communities developed a greater depth of understanding regarding global preparedness and could demonstrate verbally their understanding and application of competence in professional skills. This finding aligns with the formative experiences of the engineering global preparedness conceptual framework (Figure 16), which requires students to have experiences that support their development through testing implications and gaining concrete experience, to practice through action their global and professional competencies. However, students who did not have this experiential component to their program because they were directly enrolled in a university abroad's engineering degree program or involved in a faculty-led study abroad programs that did not have an experiential learning component did not demonstrate or discuss their development of this stage of professional or global competencies. Instead, they discussed that through observation and reflection, they were able to form abstract concepts around engineering, technology and culture – often related to the differences between their own culture and the country they were visiting. Sim's (1983) person-job congruence model of experiential learning theory explains this learning to be a personal-culture congruence that occurs within experiential learning in a new cultural context. In this model which was used in development of Yamazaki and Kayes (2004) work, individuals develop personal cross-cultural competency through transactional learning, through learning how different cultures effect them as individuals and how they as individuals have to adapt to different cultures. They were unable to take the next step, as the students who had an experiential learning project component did, to practice and take action and so be able to develop professional and global competence and reflect on the impact of their program on these their global preparedness development. These students were also not able to reflect on their personal development, the knowledge and skills they had

gained through their experience or program and assimilate these changes to their own growth and academic studies. Programs that did include an experiential learning program had different forms of reflection built into the program. Both of the short-term study abroad programs in Costa Rica and China have formal, graded reflection exercises as part of the program, while the EWB Challenge class closes with group presentations that ask students to reflect on the learning they have gained through the group project. Informally, students in the EWB student chapter may also reflect on their travel experience to the partner community during their post-trip debrief, when they present and discuss with the chapter the progress of the project and develop plans for the next steps with the community.

In addition, there were two outcomes from this study that do not relate to the study findings directly but are areas that should be considerations for future studies. Much of engineering curriculum is decontextualized, not just from culture but from the realities of working in engineering practice. Studies suggest that this is because engineering instructors often lack the experience to support students in the development of non-technical competencies, as they may as individuals, feel they do not have the competency or experience in terms of professional practice, or international experience, to support student's development in these areas (Chou & Nykanen, 2009; Paterson, O'Holleran, & Leslie, 2010). This is a barrier that is recognized by institutions and other stakeholders in engineering education, which leads to professional development opportunities for instructors in professional practice (Maturana, Tampier, Serandour, & Luco, 2014) or international development (Mattiussi, 2013), and other programs, such as faculty exchange opportunities (Morkos, Summers, & Thoe, 2014). Instructors have also found that bringing external experts into their teaching is very supportive, such as industry mentors for project design teams (Gerolamo & Gambi, 2013; Zoltowski &

Oakes, 2014), or co-teaching with non-engineering instructors from other departments or colleges who have expertise or experience in areas such as business, communication, international development or project management (Babuscia, Craig, & Connor, 2012; Liebenberg & Mathews, 2012; Sivapalan, 2017). These are all methods which, if correctly design and reflected upon by the instructors, can be key methods to either support instructors to develop, through practice and reflection, their own professional and global competence, or bringing in external expertise that can support student's development in areas instructors may not feel comfortable to do so.

Limitations

The general limitations for this study were outlined in chapter one, however it is worth further discussing the limitations in of this study in actual terms. The study was conducted at a college of engineering at a midsized, western U.S. university, which has demographic biases towards male students, as is typical of engineering programs. While the undergraduate body at the college of engineering identifies as 22% female (Institutional Research Planning and Effectiveness, 2017), of the first-year undergraduate engineering students who completed the surveys, 39% self-identified as female. Similarly, 55% of the undergraduate students that participated in the interviews for this study self-identified as female. An issue that is found with most studies of study abroad programs and other international opportunities is that due to the financial cost of most programs, there is a barrier to participation that results in many students being excluded from these opportunities, and a mobile global elite of students who have the financial and often, familial backing to undertake more than one international experience, or travel opportunity (Vandrick, 2011). In this study, this issue was found to be present, as over half of the students had had prior, international experiences and two-thirds had some level of

involvement with the EWB student chapter. This substantiates the predicted, non-probability sampling issue, in particular for the interviewed students, in that students self-selected to be involved in the study due to their interest in the research area and this inherent bias in the research data should be recognized.

A further limitation, that altered the proposed design for this study, was the different lived experiences of engineering students. Initially a comparison of all five groups included in this study had been proposed, but it very quickly became clear through the interviews that given the different educational and life experiences of the first-year students in the two Civil and Environmental Engineering classes and the students who were interviewed from the study abroad and EWB groups, it was not possible to compare their reflections on their global preparedness development given their vastly different levels of experience and education.

Conclusion

While the global context is important in engineering students' development of global preparedness and professional competence, it should be aligned with experiential learning to be effective. The gain in student's global preparedness is cumulative if students have a real (if possible), or simulated, global contextualized experience that also includes experiential learning project, such as an engineering design project situated in that global context. This study does also recognize that there is a significant financial barrier to many students participation in experiences that require international travel and that while the institution at which this study was conducted does attempt to address this issue through grant and scholarship funding for first generation, Pell grant recipients and minority student groups, the cost of study abroad will remain a significant barrier. Due to this, it is recommended that engineering education focuses on opportunities such as the EWB Challenge that allow instructors to bring international context,

and simulated engineering practice in the format of contextualized, encultured engineering group projects into their on campus curriculum. This will help to remove barriers to access for all students to experiences that support students development of professional and global competence. Curricular models which partner with external organizations, such as NGOs and engineering industry, or that draw on individual instructors own professional and international experience provides an emerging model for engineering education. This model rapidly growing across the United States, with the emergence of new courses, programs and research centers in humanitarian, human centered, and international development. These programs are fundamental to the future success of engineering education in educating all students so that they are prepared to face the complex, global problems in engineering practice.

This study also suggests that while study abroad programs will not be able to support students at great scale, due to the financial barriers inherent in such programs, it is equally important that study abroad programs are designed with similar goals of supporting students professional and global competencies. Study abroad experiences that do not include developmental experiential learning in the form of an in-depth, culturally and contextually specific team based engineering project does not support students practice and development of global and professional competencies at any increased level over their studies at their own university. Students without this, or similar, form of experiential learning project do still gain in global and cultural competency as it relates to engineering through personal-culture congruence, through their own personal observation of differences of culture, technology and engineering. From these observations they may draw abstract concepts and conceptualizations which may provide development of personal, cross-cultural competence, but do not have the opportunity to

practice and test these ideas in the real, contextualized circumstances required to develop professional and global competency through developmental learning.

Implications

The implications of this study are to support the body of literature that demonstrates the importance of experiential learning, in as real a context as possible, to engineering students' development of professional competency. Further, it demonstrates the importance of context and that global competence and awareness development can happen on campus through contextualized pseudo-experiential learning projects, such as the EWB Challenge or EWB chapter project involvement and international travel, can help, but is not required. The students' reflections also suggested that international experience does not necessarily equate to the development of global preparedness as students do not develop competence through being in and observing another culture, they require the opportunity through experiential learning to test and practice the ideas and conceptualizations they have developed through observation. Engineering study abroad or volunteer programs that integrate engineering experiential learning components in the form of a group based, globally contextualized project, prepare students to work in global engineering to a far greater extent than programs that do not as they give the students to test their conceptualizations and practice skills in context, to allow for the development of professional and global competencies.

The general implication of this is that engineering education should reflect on how global competence development is approached and that creating partnerships with universities in foreign countries to allow engineering students to study engineering in a different context may not be the panacea to solving the need for engineering students to develop global preparedness. There are solutions, such as supporting cocurricular programs such as EWB and scaffolding

them with faculty support (or as some universities have done – curricular integration), or global engineering design programs such the EWB Challenge, that may have a greater effect on engineering student’s global preparedness. These options also have the benefits of lower financial barriers to students and a greater potential impact, as they can be implemented at the collegial or departmental level unlike study abroad programs, which tend to impact a low proportion of the engineering undergraduate student body.

Direction of Future Research

There are four potential directions of future research suggested by this study, to expand the study by including additional programs and universities and to add an understanding of the importance of the instructor, and of reflective practices. Expanding the study could be done by comparing EWB student chapters and engineering study abroad programs at different universities in the United States to understand the effect of students with differing lived experiences and socio-cultural understanding on their global preparedness development through different curricular and cocurricular programs. A further expansion would be to add other engineering focused NGO’s with student chapters such as Bridges for Prosperity or Engineers for a Sustainable World and similar programs introduced earlier in this study, to further understand the effect NGO student chapter involvement has on engineering students, their global preparedness, and future careers.

Increasing the volume of data available would also allow for investigation of other factors that the data from this study suggest may impact engineering student’s global preparedness through curricular and cocurricular programs, but due to the size of the participant groups, could not be validated. Increasing the number of participants in the study would allow for a greater understanding of the role of gender, age or student generation, and the role of

faculty support and guidance in student's development of global preparedness, through professional and global competencies. The longer-term impacts of these programs on students continued interest in the engineering field and the value of their comparative global and professional competencies could also be explored, by longitudinal expansion of this study, tracking the students through their degree, graduation and future career. This would also help solve the issue highlighted in the limitation section of Chapter 5, related to the differing life and educational experience levels of students at different stages of their engineering degree program.

Two additional expansions for this study are based on understanding the effects of two influences on student's competence development that were not included in this study. The effect of instructors, their own individual experience, knowledge and interests on student's development of competency wasn't included in this study, and it is suggested that future studies develop an understanding of how instructors impact students' competency development, along with instructor's expertise to be able to deliver an experience and program design that positively effects students learning. A stage that should be included in the design of experiential and international programs is reflection on learning or competency development. In this study some of the programs investigated, but not all, have a formal or informal reflection stage to allow students to reflect and understand their own learning through the experience. This reflection stage of the conceptual framework model in Figure 16 was not investigated in this study but given its importance to student's development, it should be included in future studies.

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Appendix A – Demographics Questionnaire

Do you identify as?

- ☐ Male
- ☐ Female
- ☐ Other
- ☐ I would prefer not to identify

What is your age?

What is your engineering major?

- ☐ Civil Engineering
- ☐ Mechanical Engineering
- ☐ Environmental Engineering
- ☐ Electrical Engineering
- ☐ Chemical Engineering
- ☐ Computer Engineering
- ☐ Other/not declared yet

How do you identify yourself racially/ethnically? (Mark all that apply)

- ☐ Of African descent
- ☐ Of Asian descent (including the Indian subcontinent)
- ☐ Of Pacific Island descent
- ☐ Indigenous Person (Māori, Aboriginal, Native American, Alaskan Native etc.)
- ☐ Hispanic, Latino/Chicano
- ☐ Of Arab or Middle Eastern descent
- ☐ Of Caucasian European descent, not Hispanic

Which of the following most accurately describes your generation and citizenship? (Mark one)

- ☐ At least one of my grandparents, my parents and I were born in this country
- ☐ At least one of my parents and I were born in this country
- ☐ I was born in this country but not my parents
- ☐ Foreign born – but a citizen now of this country
- ☐ Foreign born – but not yet a citizen of this country
- ☐ Student or visitor visa

Have you ever lived, done community service, or studied abroad in another country? (Mark all that apply)

- ☐ Lived in another country less than a year
- ☐ Lived in another country 1-3 years
- ☐ Lived in another country 4 years or more
- ☐ Done community service in another country less than a year
- ☐ Done community service in another country, 1-3 years
- ☐ Done community service in another country, more than 3 years
- ☐ Studied abroad in another country, culture very much like my own
- ☐ Studied abroad in to another country, culture very different from mine

Have you been involved with Engineers Without Borders or another international engineering service organization? (Mark all that apply)

- ☐ EWB-USA Chapter member
- ☐ Have traveled abroad with an EWB-USA Chapter
- ☐ Took part in the EWB Challenge in ENGR101
- ☐ Member of another international engineering service organization (see next question)
- ☐ Traveled abroad with another international engineering service organization (see next question)

If you selected one or both of the last two options in the question above, please name the organization(s) you have been involved with?

Appendix B – EGPI Instrument - Pretest

This section of the index helps us to understand what kinds of experiences you have. Although some of the items are not directly related to engineering, they help us to understand how we might be improve our course experiences so you are fully prepared to work in the global industry. Again, the index has no right or wrong answers and is not graded. Please use the rating scale to respond to the statements below.

For the next set of items, estimate an average of how often you engaged in the following during the last two years;

	Never	A few times per year	A few times per month	A few times per week	Daily
Used a computer for school work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Discussed politics or international issues with other students outside of a formal class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Discussed racial or cultural issues outside of a formal class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Participated in at least one student club or organization	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Did volunteer work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Studied with someone from a different culture or country	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Participated in sports outside of school	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Worked on school publications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Participated in activities to protect/clean up the environment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Read a newspaper	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Watched television news	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Participated in religious activities or spiritual ceremonies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Used the internet or web outside of school	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Participated in a culturally mixed study group or recreation activity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-----------------------------------------------------------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------

This section helps us to understand how well the *midsized, western U.S. university* prepares you for working in global markets in engineering. Although some the items are not directly related to engineering, they help us to understand how we might be improve our course experiences so you are fully prepared to work in the global industry. Some of the items are worded a bit negatively and some are worded positively, so simply answer them as honestly as possible. Again, the index has no right or wrong answers and is not graded. The items may not reflect the attitudes and beliefs of the faculty at *midsized, western U.S. university*. If you believe that an item is negative, please rate it negatively, as your response should reflect your beliefs. Please use the rating scale to respond to the statements below.

Use the rating to respond to the following statements

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
It is important that universities that prepare engineers in my country provide programs designed to promote understanding among students of different ethnic and culture	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think of myself as not only a citizen of my country, but also a citizen of the world.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My nation's values are not always the best for the future of the engineering profession.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I don't think that countries with diverse religious beliefs will be able to co-exist peacefully within the near future.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
People who blame their failures on discrimination in engineering workplaces are just making excuses for not working hard enough.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Enhancing a person's ability to be part of a multicultural engineering workforce and global economy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

should be part of higher education in today's universities.

I see little value in having conversations with people in the engineering industry who's religious and political values are very different from mainstream values in my own culture or country.

☐ ☐ ☐ ☐ ☐

My country will benefit in the long run from the fact that the world is becoming more connected technologically.

☐ ☐ ☐ ☐ ☐

There is little I can do via my engineering practice to make the world a better place to live.

☐ ☐ ☐ ☐ ☐

Individual rights in engineering industries are more important than workplace policies for the common good.

☐ ☐ ☐ ☐ ☐

How I feel about an issue in the engineering field is most consistent with my own general attitudes and perspectives, and I am unlikely to be swayed by someone from the profession who sees another side.

☐ ☐ ☐ ☐ ☐

When different cultural groups have conflicting views in the engineering workplace, this will inevitably result in trouble and sometimes even violence.

☐ ☐ ☐ ☐ ☐

Immigrants from another country need to blend in like the rest of us while at work, not try to be different from their fellow engineers.

☐ ☐ ☐ ☐ ☐

Sometimes, what is good for my own country with regard to the engineering field has to be compromised to do what is good for other parts of the engineering world.

☐ ☐ ☐ ☐ ☐

The engineering field is enriched by the fact that it comprises many people from different cultures and countries.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have very little in common with people in engineering fields in underdeveloped nations.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think the engineering field needs to do more to promote the welfare of different racial and ethnic groups.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technology is an important tool for creating equality in the world.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In my future career as an engineer, having a positive effect on the quality of life for future generations will be a big factor in my choice.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I don't approve of hate-crime laws against harassment based on race, gender, religion, or sexual orientation.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
When I hear that thousands of people are starving in another country because of a disaster like a flood or earthquake, I feel frustrated that we don't do more as engineers to help.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel an obligation to speak out when I see our government doing something I consider detrimental for the engineering field.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineering field is enriched by the fact that it comprises many people from different cultures and countries.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Generally an individual's actions in the engineering workplace are too small to have an effect on the ecosystem	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I learn a great deal from discussing engineering issues with someone who disagrees with me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

When someone who has a very different opinion from mine starts talking about a religious issue in an engineering workplace, I will probably try to change the subject or get away rather than getting into the conversation.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have an obligation to “give back” to the community in some way related to the engineering profession and the broader world, monetarily or otherwise, using my engineering talents.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think it is fair for some of my taxes to go to help other countries even if everything could be spent in my own country.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I believe that my personal decisions can affect the welfare of others and what happens on a global level, in particular with regard to engineering, science and technology.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is really little or nothing I can do to improve the condition under which some people in the world live by using my engineering skills.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We should be permitted to pursue the standard of living we can afford, even if this has a slight negative impact on the environment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I try to consider different points of view on an engineering related issue before making up my own mind, even when I have a strong first impression.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It seems to me that education should focus on helping us develop career interests, not trying to get people to explore ideas and issues.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Students at universities in engineering programs should not be required to take a course to enhance better	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

international understandings if they don't want to.

It is important that we educate people to understand the impact that current engineering related policies might have on future generations.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technology is widening the divide between rich and poor countries.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Vigorous debate of different ideas related to science, engineering and technology, as part of decision-making is healthy for a democratic country.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I don't really think much about the kind of world being created and the role that engineering can play for future generations.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The needs of my own country technologically and scientifically must continue to be our highest priority in negotiating with other countries.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have contributed money or my time to a social or political cause.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Even if I do the best I can to help others with my engineering talents, it won't change the way society operates.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

This final short section helps us to understand how well you are prepared for working in global markets in engineering as it relates to your experiences. Although some of the items are not directly related to engineering, they help us to understand how we might be improve our course experiences so you are fully prepared to work in the global industry. These items related to your beliefs and experiences. Some of the items are worded a bit negatively and some are worded positively, so simply answer them as honestly as possible. Again, the index has no right or wrong answers and is not graded. Please use the rating scale to respond to the statements below.

How would you describe yourself in the following areas?

For each item, mark the circle that matches most closely your strengths/weaknesses:

	Definitely weak	Somewhat weak	Average	Somewhat Strong	Definitely Strong
Communication skills	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to work in a team	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Experience interacting with someone whose culture is different from my own	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mathematical Skills	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Knowledge about my own culture	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to Problem Solve	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Openness to being challenged or have my ideas criticized	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Leadership Ability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to see an international problem from someone else's point of view	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Knowledge about different cultures	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Skill in a language other than English or my first language	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Willingness to discuss controversial issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Academic ability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Social skills and self-confidence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Appendix C – EGPI Instrument – Posttest and Retrospective Pretest

This section helps us to understand how well *the midsized, western U.S. university* prepares you for working in global markets in engineering. Although some the items are not directly related to engineering, they help us to understand how we might be improve our course experiences so you are fully prepared to work in the global industry. Some of the items are worded a bit negatively and some are worded positively, so simply answer them as honestly as possible. Again, the index has no right or wrong answers and is not graded. The items may not reflect the attitudes and beliefs of the faculty at *the midsized, western U.S. university*. If you believe that an item is negative, please rate it negatively, as your response should reflect your beliefs. Please use the rating scale to respond to the statements below.

Please note: Green columns are your how you feel now. Purple columns are how you would have responded before the start of this course. Please select one green option (now) and one purple option (pre-course) for each line. (the green options are the first five, the purple are the second five)

Use the rating to respond to the following statements:

	Now: Strongly disagree	Now: Somewhat disagree	Now: Neither agree nor disagree	Now: Somewhat agree	Now: Strongly agree	Pre- course... (five options repeated)
It is important that universities that prepare engineers in my country provide programs designed to promote understanding among students of different ethnic and culture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I think of myself as not only a citizen of my country, but also a citizen of the world.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
My nation's values are not always the best for the future of the engineering profession.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't think that countries with diverse religious beliefs will be	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

able to co-exist peacefully within the near future.						
People who blame their failures on discrimination in engineering workplaces are just making excuses for not working hard enough.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Enhancing a person's ability to be part of a multicultural engineering workforce and global economy should be part of higher education in today's universities.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I see little value in having conversations with people in the engineering industry whose religious and political values are very different from mainstream values in my own culture or country.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
My country will benefit in the long run from the fact that the world is becoming more connected technologically.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There is little I can do via my engineering practice to make the world a better place to live.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Individual rights in engineering industries are more important than workplace policies for the common good.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

How I feel about an issue in the engineering field is most consistent with my own general attitudes and perspectives, and I am unlikely to be swayed by someone from the profession who sees another side.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
When different cultural groups have conflicting views in the engineering workplace, this will inevitably result in trouble and sometimes even violence.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Immigrants from another country need to blend in like the rest of us while at work, not try to be different from their fellow engineers.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sometimes, what is good for my own country with regard to the engineering field has to be compromised to do what is good for other parts of the engineering world.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The engineering field is enriched by the fact that it comprises many people from different cultures and countries.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I have very little in common with people in engineering fields in underdeveloped nations.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I think the engineering field needs to do more to promote the welfare	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

of different racial and ethnic groups.						
Technology is an important tool for creating equality in the world.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
In my future career as an engineer, having a positive effect on the quality of life for future generations will be a big factor in my choice.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't approve of hate-crime laws against harassment based on race, gender, religion, or sexual orientation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
When I hear that thousands of people are starving in another country because of a disaster like a flood or earthquake, I feel frustrated that we don't do more as engineers to help.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I feel an obligation to speak out when I see our government doing something I consider detrimental for the engineering field.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The engineering field is enriched by the fact that it comprises many people from different cultures and countries.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Generally an individual's actions in the engineering workplace are too small to have an effect on the ecosystem	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

I learn a great deal from discussing engineering issues with someone who disagrees with me.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
When someone who has a very different opinion from mine starts talking about a religious issue in an engineering workplace, I will probably try to change the subject or get away rather than getting into the conversation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I have an obligation to “give back” to the community in some way related to the engineering profession and the broader world, monetarily or otherwise, using my engineering talents.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I think it is fair for some of my taxes to go to help other countries even if everything could be spent in my own country.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that my personal decisions can affect the welfare of others and what happens on a global level, in particular with regard to engineering, science and technology.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There is really little or nothing I can do to improve the condition under which some people in the world live by using my engineering skills.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

We should be permitted to pursue the standard of living we can afford, even if this has a slight negative impact on the environment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I try to consider different points of view on an engineering related issue before making up my own mind, even when I have a strong first impression.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It seems to me that education should focus on helping us develop career interests, not trying to get people to explore ideas and issues.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Students at universities in engineering programs should not be required to take a course to enhance better international understandings if they don't want to.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It is important that we educate people to understand the impact that current engineering related policies might have on future generations.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Technology is widening the divide between rich and poor countries.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vigorous debate of different ideas related to science, engineering and technology, as part of decision-making is	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

healthy for a democratic country.						
I don't really think much about the kind of world being created and the role that engineering can play for future generations.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The needs of my own country technologically and scientifically must continue to be our highest priority in negotiating with other countries.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I have contributed money or my time to a social or political cause.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Even if I do the best I can to help others with my engineering talents, it won't change the way society operates.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

This final short section helps us to understand how well you are prepared for working in global markets in engineering as it relates to your experiences. Although some of the items are not directly related to engineering, they help us to understand how we might be improve our course experiences so you are fully prepared to work in the global industry. These items related to your beliefs and experiences. Some of the items are worded a bit negatively and some are worded positively, so simply answer them as honestly as possible. Again, the index has no right or wrong answers and is not graded. Please use the rating scale to respond to the statements below.

Please note: Green columns are your how you feel now. Purple columns are how you would have responded before the start of this course. Please select one green option (now) and one purple option (pre-course) for each line. (the green options are the first five, the purple are the second five)

How would you describe yourself in the following areas? For each item, mark the circles that matches most closely your strengths/weaknesses:

	Now: Definitely weak	Now: Somewhat weak	Now: Average	Now: Somewhat Strong	Now: Definitely Strong	Pre- course: Definitely weak
Communication skills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ability to work in a team	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Experience interacting with someone whose culture is different from my own	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mathematical Skills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Knowledge about my own culture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ability to Problem Solve	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Openness to being challenged or have my ideas criticized	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Leadership Ability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ability to see an international problem from someone else's point of view	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Knowledge about different cultures	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Skill in a language other than English or my first language	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Willingness to discuss controversial issues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Academic ability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Social skills and self-confidence	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Appendix D – Institutional Review Board (IRB) Approval

- November 6th 2015 - Initial Notice of Approval
- September 23rd 2016 - Notice of Approval to Extend study
- January 13th 2017 - Approval to add additional CIVE103 study population, EGPI instrument
and
interview protocol
- February 3rd 2017 - Approval to add Study Abroad study populations
- April 9th 2017 - Approval to add EWB-USA student chapter study populations
- August 23rd 2017 - Approval to add replacement control population
- October 25th 2017 - Notice of Approval to Extend study



Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011 Fort Collins,
CO
TEL: (970) 491-1553
FAX: (970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE: November 06, 2015
TO: Siller, Thomas
Cook, Alistair, McLean, David
FROM: Swiss, Evelyn, Coordinator, CSU IRB 2
PROTOCOL TITLE: Engineers Without Borders Challenge
FUNDING SOURCE: NONE
PROTOCOL NUMBER: 15-6131H
APPROVAL PERIOD: Approval Date: November 06, 2015 Expiration Date: October 08, 2016

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Engineers Without Borders Challenge. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

Important Reminder: If you will consent your participants with a signed consent document, it is your responsibility to use the consent form that has been finalized and uploaded into the consent section of eProtocol by the IRB coordinators. Failure to use the finalized consent form available to you in eProtocol is a reportable protocol violation.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu

Evelyn Swiss, Senior IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu

Tammy Felton-Noyle, Assistant IRB Coordinator - (970) 491-1655; Tammy.Felton-Noyle@Colostate.edu

Swiss, Evelyn

Approval is to recruit up to 150 participants with the approved verbal script recruitment and consent. The above-referenced project was approved by the Institutional Review Board with the condition that the approved consent form is signed by the subjects and each subject is given a copy of the form. NO changes may be made to this document without first obtaining the approval of the IRB

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE: September 23, 2016
TO: Siller, Thomas
Cook, Alistair, McLean, David
FROM: Swiss, Evelyn, CSU IRB 2
PROTOCOL TITLE: Engineers Without Borders Challenge
FUNDING SOURCE: NONE
PROTOCOL NUMBER: 15-6131H
APPROVAL PERIOD: Approval Date: October 08, 2016 Expiration Date: October 07, 2017

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Engineers Without Borders Challenge. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

Important Reminder: If you will consent your participants with a signed consent document, it is your responsibility to use the consent form that has been finalized and uploaded into the consent section of eProtocol by the IRB coordinators. Failure to use the finalized consent form available to you in eProtocol is a reportable protocol violation.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

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Evelyn Swiss, Senior IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu

Tammy Felton-Noyle, Assistant IRB Coordinator - (970) 491-1655; Tammy.Felton-Noyle@Colostate.edu



Swiss, Evelyn

Approval to recruit the remaining 42 participants with the approved recruitment and consent procedures. The above-referenced project was approved by the Institutional Review Board with the condition that the approved consent form is signed by the subjects and each subject is given a copy of the form. NO changes may be made to this document without first obtaining the approval of the IRB.

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE: January 13, 2017
TO: Siller, Thomas
Cook, Alistair, McLean, David
FROM: Swiss, Evelyn, CSU IRB 2
PROTOCOL TITLE: Engineers Without Borders Challenge
FUNDING SOURCE: NONE
PROTOCOL NUMBER: 15-6131H
APPROVAL PERIOD: Approval Date: January 04, 2017 Expiration Date: October 07, 2017

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Engineers Without Borders Challenge. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

Important Reminder: If you will consent your participants with a signed consent document, it is your responsibility to use the consent form that has been finalized and uploaded into the consent section of eProtocol by the IRB coordinators. Failure to use the finalized consent form available to you in eProtocol is a reportable protocol violation.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu

Evelyn Swiss, Senior IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu

Tammy Felton-Noyle, Assistant IRB Coordinator - (970) 491-1655; Tammy.Felton-Noyle@Colostate.edu



Swiss, Evelyn

Amendment is approved to 1.add two new validated quantitative instruments and a revised set of validated interview/focus group questions, and 2.to increase the approved participants to include 220 CIVE 103 students and 200 MECH201 students as a control study population. The total number of participants approved to recruit is: 150 (original approval) + 220 + 200 = 570. Approval also includes approval of the updated focus group and survey

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE: February 03, 2017
TO: Siller, Thomas
Cook, Alistair, McLean, David
FROM: Swiss, Evelyn, CSU IRB 2
PROTOCOL TITLE: Engineers Without Borders Challenge
FUNDING SOURCE: NONE
PROTOCOL NUMBER: 15-6131H
APPROVAL PERIOD: Approval Date: January 30, 2017 Expiration Date: October 07, 2017

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Engineers Without Borders Challenge. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

Important Reminder: If you will consent your participants with a signed consent document, it is your responsibility to use the consent form that has been finalized and uploaded into the consent section of eProtocol by the IRB coordinators. Failure to use the finalized consent form available to you in eProtocol is a reportable protocol violation.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu

Evelyn Swiss, Senior IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu

Tammy Felton-Noyle, Assistant IRB Coordinator - (970) 491-1655; Tammy.Felton-Noyle@Colostate.edu



Swiss, Evelyn

Amendment is approved to add 30 engineering and construction management undergraduate students. Total participants approved to recruit: 370 1st year engineering students; 200 second year students, and 30 engineering and construction management undergraduate students) with the approved recruitment and consent.

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE: April 09, 2017
TO: Siller, Thomas
Cook, Alistair, McLean, David
FROM: Swiss, Evelyn, CSU IRB 2
PROTOCOL TITLE: Engineers Without Borders Challenge
FUNDING SOURCE: NONE
PROTOCOL NUMBER: 15-6131H
APPROVAL PERIOD: Approval Date: April 01, 2017 Expiration Date: October 07, 2017

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Engineers Without Borders Challenge. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

Important Reminder: If you will consent your participants with a signed consent document, it is your responsibility to use the consent form that has been finalized and uploaded into the consent section of eProtocol by the IRB coordinators. Failure to use the finalized consent form available to you in eProtocol is a reportable protocol violation.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu

Evelyn Swiss, Senior IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu

Tammy Felton-Noyle, Assistant IRB Coordinator - (970) 491-1655; Tammy.Felton-Noyle@Colostate.edu



Swiss, Evelyn

Amendment is approved via the expedite-review process to add an additional 10 engineering undergraduate students (students who undertook a CSU study abroad program or are a member of the Engineers without Borders USA), and to use the updated consent for this population. No change in risk.

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE: August 23, 2017
TO: Siller, Thomas
Cook, Alistair, McLean, David
FROM: Swiss, Evelyn, CSU IRB 2
PROTOCOL TITLE: Engineers Without Borders Challenge
FUNDING SOURCE: NONE
PROTOCOL NUMBER: 15-6131H
APPROVAL PERIOD: Approval Date: August 14, 2017 Expiration Date: October 07, 2017

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Engineers Without Borders Challenge. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

Important Reminder: If you will consent your participants with a signed consent document, it is your responsibility to use the consent form that has been finalized and uploaded into the consent section of eProtocol by the IRB coordinators. Failure to use the finalized consent form available to you in eProtocol is a reportable protocol violation.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu

Evelyn Swiss, Senior IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu

Tammy Felton-Noyle, IRB Biomedical Coordinator - (970) 491-1655; Tammy.Felton-Noyle@Colostate.edu



Swiss, Evelyn

Amendment is approved to update approved participants to recruit: Addition of 200 first-year students and up to an additional 60 engineering undergraduate students; the 200 second-year students that had previously been approved (Amendment 1) are no longer planned to be recruited.

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE: October 25, 2017
TO: Siller, Thomas
Cook, Alistair, McLean, David
FROM: Swiss, Evelyn, CSU IRB 2
PROTOCOL TITLE: Engineers Without Borders Challenge
FUNDING SOURCE: NONE
PROTOCOL NUMBER: 15-6131H
APPROVAL PERIOD: Approval Date: October 08, 2017 Expiration Date: October 07, 2018

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Engineers Without Borders Challenge. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

Important Reminder: If you will consent your participants with a signed consent document, it is your responsibility to use the consent form that has been finalized and uploaded into the consent section of eProtocol by the IRB coordinators. Failure to use the finalized consent form available to you in eProtocol is a reportable protocol violation.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu
Evelyn Swiss, Senior IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu
Tammy Felton-Noyle, IRB Biomedical Coordinator - (970) 491-1655; Tammy.Felton-Noyle@Colostate.edu



Swiss, Evelyn

Approval is to continue to recruit the remaining participants with the approved recruitment and consent. Balance remaining to recruit: 42 first-year undeclared engineering students; 37 first-year students; 200 second-year students; 23 engineering and construction management undergraduate students; 70 engineering undergraduate students. The above-referenced project was approved by the Institutional Review Board with the condition that the approved consent form is signed by the subjects and each subject is given a copy of the form. NO changes may be made to this document without first obtaining the approval of the IRB.

Approval Period: October 08, 2017 through October 07, 2018

Appendix E – IRB Approved Recruitment Scripts

Verbal Recruitment Script for use in Classrooms

Hello, my name is Alistair and I am a researcher from a *midsized, western U.S. university* in the School of Education. We are conducting a research study on Engineering Global Competency and I am interested in your experiences doing the challenge and if it has affected your thoughts about engineering. The title of our project is EWB Challenge. The Principal Investigator is Tom Siller, your instructor and I am the Co-Principal Investigator.

We would like you to take this survey. Participation will take approximately ten minutes. Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participation at any time without penalty. You may choose not to answer the survey or any question within it. Your identity or personal information will not be disclosed in any publication that may result from the study and will not be shared with your instructor as this is a completely separate process from your class which is why he has stepped out of the room at the moment.

We will not collect your name on the survey but will collect your student ID – this is to allow us to link your responses at the start of the semester with your responses at the end of the semester. These ID's will not be shared with your instructor and these surveys will be kept by me in secure location that they cannot access. When we report and share the data with others, we will combine the data from all participants. There are no known risks or direct benefits to you, and our purpose is to help Tom improve the course for next year and to allow both of us to present this program to other universities in the hope of getting more schools in the US involved. This research will

benefit the academic community because it helps us to understand if this helps students become more globally competent, which engineering industry tells us is vitally important to your futures as practicing engineers. If you have questions about your rights as a volunteer in this research, contact the *midsized, western U.S. university* IRB at: RICRO_IRB@mail; 970-491-1553.

I also have a sign-up sheet for a focus group or interviews we would like to hold towards the end of the semester, your participation in this is entirely voluntary and it shouldn't take more than an hour. We would just like to ask those of you that are interested some further, deeper questions on your learning in this class. If you are interested, please put your email address (not your name) down on the sign-up sheet and I'll get in contact with you in the next day or two with further details. Thanks again for your time and we really do appreciate your help with our research.

Do you have any questions before we get started?

Email Recruitment template for interviews

Dear <Student>

My name is Alistair and I am a researcher from *a midsized, western U.S. university* in the school of education. We are conducting a research study on Engineering Global Competency and I am interested in your studying abroad and if it has affected your thoughts about engineering/construction management <delete as appropriate>. The title of our project is EWB Challenge. The Principal Investigator is Tom Siller, and I am the Co-Principal Investigator.

We would very much appreciate if you had 20-30 minutes at a place and time of your convenience that I could ask you a few questions about your study abroad experience and if it effected your understanding of engineering and your future career plans? participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participation at any time without penalty. You may choose not to answer any question in the interview. Your identity or personal information will not be disclosed in any publication that may result from the study and will not be shared with your instructors.

There are no known risks or direct benefits to you, and our purpose is to help improve engineering education at *the midsized, western U.S. university* and to allow both of us to present a global engineering programs currently taught at *the midsized, western U.S. university* to other universities in the hope of getting more schools in the US involved. This research will benefit the academic community because it helps us to understand if this helps students become more

globally competent, which engineering industry tells us is vitally important to your futures as practicing engineers. If you have questions about your rights as a volunteer in this research, contact the *midsized, western U.S. university* IRB at: RICRO_IRB@mail.; 970-491-1553.

If you have time and would like to be part of this research, please respond to this email or contact me on 970-213-9358 we appreciate your time and support in enabling more students to take part in global engineering programs and projects.

Yours Sincerely

Alistair Cook

Verbal Recruitment Script for use recruitment of EWB-USA Student chapter members

Hello, my name is Alistair and I am a researcher from *a midsized, western U.S. university* in the school of education. We are conducting a research study on Engineering Global Competency and I am interested in your work with EWB-USA and if it has affected your thoughts about engineering. The title of our project is EWB Challenge. The Principal Investigator is Tom Siller, and I am the Co-Principal Investigator.

We would very much appreciate if you had 20-30 minutes at a place and time of your convenience that I could ask you a few questions about your study abroad experience and if it effected your understanding of engineering and your future career plans? participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participation at any time without penalty. You may choose not to answer any question in the interview. Your identity or personal information will not be disclosed in any publication that may result from the study and will not be shared with your instructors.

If you are interested I have a sign-up sheet at the back of the room, it will ask for your name and email so that I can contact you with further details.

Appendix F – IRB Approved Consent Forms

January 13th 2017 - Survey Consent Form

April 9th 2017 - Interview Consent Form

Consent to Participate in a Research Study Colorado State University

TITLE OF STUDY: Engineers Without Borders Challenge

PRINCIPAL INVESTIGATOR: Thomas Siller, College of Engineering,
Thomas.siller@colostate.edu

CO-PRINCIPAL INVESTIGATOR: Alistair Cook, PhD Student, School of Education,
alistair.cook@colostate.edu

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? You are being invited to take part in this research as we want to gain the opinions of students who have taken part in the Engineers Without Borders Challenge project, during your fall 2015 class.

WHO IS DOING THE STUDY? The research team is Tom Siller and Alistair Cook, they first introduced the EWB Challenge as part of this class in fall of 2014. Alistair has worked for EWB in the UK and worked with this project there, he is currently doing a PhD in engineering education here at CSU.

WHAT IS THE PURPOSE OF THIS STUDY? The purpose of this study is to understand how students use the EWB Challenge project to question their understanding of engineering and the engineering disciplines and how engineering applies to global challenges? The investigators also hope to understand how the EWB Challenge effects students global competency, compared with students who undertake a non-international design project.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? We will ask you to complete a survey in this class at the start and end of the semester, this will take about 20 minutes to complete.

WHAT WILL I BE ASKED TO DO? The survey will ask you to share some demographic data, such as age, gender you identify as, travel experience and background. It will then ask you to respond to various questions on a scale of 1-5 related to global engineering competency and experience. The survey will ask for your student ID so that we can link your start of semester and end of semester surveys but this ID will be converted to a confidential code held only by the researcher (Alistair Cook) before any results are shared with your instructor. The results will not be shared with your instructor until after this semester has ended and grading is complete.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY?

There are no direct benefits from taking part in this study.

DO I HAVE TO TAKE PART IN THE STUDY?

Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHO WILL SEE THE INFORMATION THAT I GIVE?

The start of semester and end of semester surveys will not include your name, but will have your student ID so that they can be linked. Once the surveys are linked, your student ID number will be converted to a confidential code held only by the researcher (Alistair Cook) before any results are shared. No one, not even the research team, will be able to link your survey data to you.

WHAT IF I HAVE QUESTIONS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Alistair Cook at 970-213-958 or alistair.cook@colostate.edu. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; 970-491-1553. We will give you a copy of this consent form to take with you.

For this study, the survey will ask for your student ID so that we can link your start of the semester to the end of the semester surveys; however, this ID will be converted to a confidential code held only by the researcher (Alistair Cook) before any results are shared. Only the researcher (Alistair Cook) will have access to the link between you, your code, and your data and this will never be shared with your instructor. The only exceptions to this are if we are asked to share the research files for audit purposes with the CSU Institutional Review Board ethics committee, if necessary. In addition, for funded studies, the CSU financial management team may also request an audit of research expenditures. For financial audits, only the fact that you participated would be shared, not any research data. When we write about the study to share with other researchers, we will write about the combined information we have gathered. You will not be identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing two pages.

Signature of person agreeing to take part in the study

Date

Printed name of person agreeing to take part in the study

Alistair Cook

Name of person providing information to participant

Date

Signature of Research Staff

ID code - 12

Consent to Participate in a Research Study Colorado State University

TITLE OF STUDY: Engineers Without Borders Challenge

PRINCIPAL INVESTIGATOR: Thomas Siller, Ph.D., Associate Professor, College of Engineering, Thomas.siller@colostate.edu

CO-PRINCIPAL INVESTIGATOR: Alistair Cook, PhD Student, School of Education, alistair.cook@colostate.edu

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? You are being invited to take part in this research as we want to gain the opinions of students who have taken part engineering design experiences, either in the US or another country as part of a study abroad or volunteer program.

WHO IS DOING THE STUDY? The research team is Tom Siller and Alistair Cook, they first introduced the EWB Challenge as part of this class in fall of 2014. Alistair has worked for EWB in the UK and worked with this project there, he is currently doing a PhD in engineering education here at CSU.

WHAT IS THE PURPOSE OF THIS STUDY? The purpose of this study is to understand how students use the design projects and international experiences to question their understanding of engineering and the engineering disciplines and how engineering applies to global challenges? The investigators also hope to understand how your study experience effects students global competency, compared with students who undertake a non-international design project.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? We will contact you to set up a one hour focus group with other members of your class or a 30 minute interview. The focus group or interview will take place in one of the civil engineering conference rooms, depending on room availability.

WHAT WILL I BE ASKED TO DO? During the focus group session or interview we will ask you to discuss how you feel your design project or study abroad went as an experience for you and how it relates to how you understand the role of an engineer and your future plans. We will be audio recording the session to ensure that we don't miss any details of your discussion and this recording will be deleted once we have taken notes. Our notes will not include any identifying information and if you would like, we would be glad to share these with you. Taking part in this study is completely voluntary and anything discussed in the sessions is confidential and will not be used as part of grading.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY?

There are no direct benefits from taking part in this study.

DO I HAVE TO TAKE PART IN THE STUDY?

Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHO WILL SEE THE INFORMATION THAT I GIVE?

This study is anonymous. For this study, we are not obtaining your name or other identifiable data from you, so nobody (not even the research team) will be able to identify you or your data.

WHAT IF I HAVE QUESTIONS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Alistair Cook at 970-213-958 or alistair.cook@colostate.edu. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at RICRO_IRB@mail.colostate.edu; 970-491-1553. We will give you a copy of this consent form to take with you.

For this study, we will assign a code to your data (see below) so that the only place your name will appear in our records is on the consent and in our data spreadsheet which links you to your code. Only the research team will have access to the link between you, your code, and your data. When we write about the study to share with other researchers, we will write about the combined information we have gathered. You will not be identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing two pages.

Signature of person agreeing to take part in the study

Date

Printed name of person agreeing to take part in the study

Alistair Cook

Name of person providing information to participant

Date

Signature of Research Staff

ID code - 12

Appendix G – Codebook

Global Competencies

Community Service, working with local communities

Foreign Languages, language barriers

Reflections on cultural relevance of engineering

Global and cultural awareness

Global, international, transnational

Working with diverse teams, communities

Global Citizenship

Professional Competencies

Teamwork

Communication

Ethics

Leadership

Innovation and Entrepreneurship

Project Management

Other non-technical skills

Impacts and Differences

How EWB, study abroad or class has impacted how you think about engineering

Has international travel affected them, differences they noticed

Different styles of teaching and learning

Reflections on gender in engineering

Student career and study choices

Why students chose to study engineering

Why students chose to study abroad

Why students chose to join EWB

Students future career or study plans

Appendix H – Interview Protocol

Thanks for agreeing to take part in this interview, I really appreciate you taking the time to help with our research. Would you like me to explain a little bit about this project and why we are doing it?

(If yes) Sure, I'm working with some professors in engineering and education to try and understand how international experiences such as study abroad, EWB, classes here on campus related to global engineering effect engineering students' development of global and professional competencies and skills. I would like to ask you some questions about your time here at CSU, why you chose to study engineering, how your class/international experience went and your reflections on what you experienced and learned from it.

Do you have any questions about this research?

...

As a reminder, you are free to stop the interview at any time, choose not to answer any question or request that your responses are deleted or not used. With your permission, I would like to record our conversation, after the interview I will transcribe the recording and send it to you, having removed any information that could identify you, this is just another opportunity for you to check that I have correctly transcribed your words, and to give you a chance to remove anything you are not comfortable with me sharing or using as part of this research. Again, if you choose to, you can also let me know if you are no longer comfortable with me using your interview as part of this research project. Here is a copy of the IRB consent form, please read through it and if you are okay with the contents, sign and date at the end please.

[Check IRB consent form is completed correctly, countersign]

....

May I record this interview, or would you prefer I take written notes?

Great, could you also please complete this demographic questionnaire, and please ask if any of the questions are not clear?

[Collect Demographic questionnaire]

[Start recording, or taking notes]

Okay, let's start with, why did you choose to study engineering?

[Prompts – family, school, teachers, physics/math/engineering classes/summer camps]

Why did you choose to join EWB/do a study abroad?

[Prompts – family, international travel, language, social, volunteering]

Or

What did you think of CIVE102/CIVE103 compared to your other classes?

[first engineering class, engineering classes in high school, instructor]

Did the <class or program> change the way you think about engineering?

[Prompts – Culture, technical, new experiences, projects]

Did this <class or program> affect your thinking about the cultural relevance of engineering?

[Prompts – differences, compare, culture, projects]

Do you think your <class or program> has had any effect (positive or negative) on your non-technical engineering skills, such as teamwork, communication, leadership, and global and cultural adaptability?

[Prompts – PLI's, class projects]

Is there anything you think I should have asked you about, or that you would like to share that we have not already covered?

Okay, well, thank you again for taking part in this, it's been very helpful to hear your reflections and thoughts on your <class or program>. Just as a reminder, I will send you a copy of this transcript in the next week, if you would like to, please check through it and let me know of any corrections or parts you would like removed and I'll make those changes, or if you no longer consent for your responses to be part of this research project. If I do not hear from you within a couple of weeks, I'll assume it's all okay and start the analysis of your interview.